

An investigation into achieving visual narration using photochromic dyes on a textile substrate

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Abstract

Photochromic dyes have the unique property of being colourless until exposed to ultraviolet (UV) light. Their application within design has thus far been basic, predominantly developing the medium as it is exposed to natural UV light. Therefore, by exploring the dyes' colours and movement when printed on a textile substrate and developed by artificial UV light, this thesis investigates their ability to create a form of visual narrative. Using the dyes' colours to evoke a change in emotion set the parameters for answering this aim.

Testing the interactions of the dyes' colours in sunlight, on a range of substrates and in varied combinations, provided initial knowledge of how they perform in this medium. Whilst the stylistic techniques of French Impressionist films provided configurations with which to explore the movement of the dyes, research on colour showed the diversity of ways in which it is able to be used to express emotion.

Two custom built UV LED arrays, manually operated then software driven, enabled the dyes' development times and intervals to be controlled. Design questions were then answered by combining these factors with the dyes' fading speeds. Storyboarding photographs became an important part of the analysis and reflection process whilst filming also assisted in observing their transient nature. This work revealed that a new methodology, that was based on placement and sequencing, would be necessary when designing with dyes that move.

Design exploration illustrated how using two dyes, from opposite ends of both the fading and emotional spectrum, mixed by printing, could create a colour change, as they faded, when they were developed in a linear sequence. Subsequently, by combining abstract representational imagery with variations on the stylistic film techniques, to alternately develop two dyes, it was illustrated how, by varying their development intervals, these dyes have the potential to create a visual narrative that evokes a change of emotion in the viewer.

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La hawla wa la quwwata ila Billah

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Chapter 1

Literature Review

Literature Review

1.1 Introduction

Although technology advances and inventions bring developments that support and enhance our daily interactions, we remain sentient beings with our humanness defined by our feelings and emotions, and these characteristics govern what we do. However, we do have a need to use these things, products that are inanimate and do not in themselves contain or express feelings. As Boradkar states, ‘These things shape our world.’ [1.1].

When technology is discussed and described words such as electronics, computer, wiring, plastic, hardware and software are used. These words imply a feeling of hardness or rigidity, a lack of tactility, even if this is not necessarily so. Many technologies are soft, pliable and/or tactile. For example, although the back of an itouch is rigid and hard, it is also smooth and fine, qualities that give the user a surface to caress as it is cradled in their hand. However, overall the image of a surface that is tactile and cosy is not initially forthcoming even though the wires and electronic elements that are a part of the product are encased and hidden. Cloth is more comforting.

Traditionally textiles are, and have always been, used for wrapping, warming, carrying, expressing, enhancing, protecting, hiding and communicating [1.2] and remain very prominent and present in our daily lives. According to Stacey Burr, founder of Textronics, a company developing electronic textiles and clothing, “about 70% of the materials that people come in contact with are fabrics” [1.3]. Throughout history the design and manufacture of fashion and textiles has been closely related to scientific and industrial innovation [1.4]. In recent decades there has been greatly increased development within the technical and functional textiles area and an escalating interaction between textile design, technology and science can be observed [1.5], with innovation in fields as wide-ranging as electronics, medicine, sporting equipment, fashion, wireless communication and the military and space agencies [1.6]. For example, textiles are now able to sense how much light or sound to absorb, measure pulse and immune system resistance and cool overheated firemen. Additionally, gloves contain microphones, cement is reinforced with textile material and solar cells are integrated into fabric [1.7]. Textiles are also able to change colour. This may be in

response to water using hydrochromic inks [1.8], to heat using thermochromic inks [1.9] or in response to light using photochromic dyes, the latter upon which this research is based.

Photochromic dyes have the unique property of being colourless until exposed to sufficient UV light, either natural (sunlight) or artificial, when they become brightly coloured. The dyes then fade back (at different speeds depending on the dye) to colourless once they are removed from that source of light [1.10] [1.11]. With their chameleon qualities, photochromic dyes generally categorise and place the materials in which they are incorporated amongst members of the intelligent or smart textiles field. The term smart textiles implies that they have qualities that are cleverer, perhaps more beneficial to us, than traditional textiles and indeed, while textile designing on fabric conventionally involves a design that is fixed, i.e., stationary, working with photochromic dyes introduces the element of movement. This allows for the suggestion of something else to occur. By using this very ‘intelligent’ attribute of these dyes in a certain way, I am aiming to capture something intangible, giving the dyes and their encompassing materials qualities more associated with the ethereal, and in doing so shift them towards a different arena, one that is more closely associated with the poetic as opposed to the scientific. By using this smart technology to capture and express emotion a form of narrative would be revealed. In effecting this, I am attempting to bridge the space between the potentially disparate entities of technology and human need. The textile artefact would then be placed at the crossroads of the metaphysical and the technological, thereby enhancing the home environment in which it is placed. In this form, this textile piece opens up new possibilities in ways of working and communicating with others, either deliberately and overtly or in a more concealed and secretive way. This added dimension to the cloth, by the application of these dyes, would also build on the already substantial uses of traditional textiles.

To reflect the topic of this research, which draws on information from a diversity of fields, I will look at the latest literature in the areas of narrative, French Impressionist film and colour in the context in which they relate to this project. A review of the way narrative is expressed, either overtly or subtly, in various forms within interior design products will be given. The design applications within which photochromic dyes have been used will also be illustrated.

Colour changing imagery is reminiscent of the moving imagery in films, and so lends itself to narrative. Therefore, the theoretical understanding of narrative as it is applied to new media will be researched. This will help to contextualise the practical work that will be undertaken, whilst gaining an understanding of its relationship with other works that have, or are being, developed in this field.

French Impressionist films are unusual in that stylistic techniques were used within the films as a way of assisting with the telling of a story. They acted as a support in the expression of moods and atmosphere, for example, enhancing the ability to create a sense of serenity or drama within a scene or as scenes changed from one to another. Research will determine how these techniques may be used as a starting point and for inspiration when applying movement to the dyes.

Photochromic dyes are coloured which means that as they appear and disappear the observer is able to see their colours appear and disappear. Colour is used as a signifier of emotion, therefore colour and how it is used by artists and designers to capture or express emotion will be researched. The resulting information will be used as a guide in the exploration of the dyes' application to the textile substrate to achieve the project aim.

1.2 Narrative

As new media and forms of technology are created, alternative avenues are available in which narrative, an art that has been practiced using the simplest to the most complex of tools, can be explored, defined and expressed.

1.2.1 Narrative within different media

Barbara Barry, in *Storybeads - a wearable for distributed and mobile storytelling*, says that stories live in and are influenced by their container, the medium of their telling [1.12]. Her thesis investigates the life of a story as it is fashioned by an artist, an author or a director and follows it to its internal interpretation by the audience. Barry goes on to say that conventions of story making are identified as media or container specific and that oral stories, films and photographs have distinct conventions and methods for building stories. She also states that as new containers are invented, the activity of story construction, for that particular container, evolves as users find creative ways to express themselves within a new medium [1.13].

In *Visual-Narrative and Virtual Reality*, Carroll, Smyth and Dryden discuss how virtual reality is a new medium that needs to develop its own language so that it can join cinema and television as a successful artistic medium. The authors use cinema as a benchmark as they look at the value of the image and the viewer's engagement with it in the virtual reality world. They also refer to Bordwell and Thompson's opinion that a film's use of narrative form cannot be studied apart from the film style, i.e., mise en scene, cinematography, editing and sound, and continue by saying that the same is true for the medium of virtual reality where a narrative emerges from the user's experience of the virtual reality environment and the medium and the narrative are inextricably dependent on one another. Carroll et al also say that it is important to bear in mind that as media and technologies change and develop their relationship to and dependence on narratives also changes [1.14].

Sonja Andrew defines visual narrative within textiles as, 'a story or message that can be expressed by images without the use of words. This usually needs figurative imagery arranged in some type of sequential form (e.g. toile de jouy) but a single work can also create a visual narrative through one 'picture' [1.15]. She also states that, 'communicative textiles don't necessarily have to be visual narratives, they could communicate meaning based on their form, colour or material, evoking a more emotive reaction based on associations with other objects or experiences (which may be personal experiences or 'culturally learned' reactions)' [1.16].

When using the relatively new technology of photochromic dyes in a new way, i.e., applying them to a textile substrate and controlling their appearance and disappearance with artificial UV light sources, their ability to create a visual narrative will be judged against Andrew's definition. The results of the research will also determine whether or not they are able to create a communicative textile.

1.2.2 French Impressionist films to express narrative

A viewer makes sense of a film by recognising the overall pattern of relationships among the various elements of that film, relating them to one another and reacting to them in various ways. Two sets of these elements, narrative and stylistic, help give a film unity. The narrative elements constitute the film's story and we, as viewers, link and compare these narrative elements. Bordwell and Thompson explain how the tornado causes Dorothy's trip in the Wizard of Oz and how we identify the characters in

Oz as similar to the characters in Dorothy's Kansas life. The set of stylistic elements: the way the camera moves, the patterns of colour in the frame, the use of music, and other devices, can also be connected. Our minds seek to connect these elements, the narrative ones and the stylistic ones, to one another so that we are able to make sense of the film as a whole [1.17].

In his thesis, *French Impressionist Cinema: Film Culture, Film Theory, and Film Style*, Bordwell identifies that an avant-garde movement in French film emerged and flourished between 1918 and 1928. This movement was generally called French Impressionism and created an indigenous film culture, a theory of cinema and a distinct film style [1.18].

In *Film Art: An Introduction*, Bordwell and Thompson describe what motivated the young French Impressionist filmmakers. Whereas the previous generation had regarded it as a commercial craft, these younger filmmakers proclaimed cinema to be an art comparable to poetry, painting and music. Above all, it should be an occasion for the artist to express feelings [1.19]. They believed the recording of material reality was not sufficiently artistic ... something not immediately or materially apparent must be brought out, evoked or led forth. Jean Epstein claimed that an object has a 'soul' which film reveals ... in a film an object becomes animated and expressive, baring its previously concealed essence [1.20].

As well as gaining its name because of its interest in giving narration considerable psychological depth [1.21], the Impressionist movement also earned its name for its use of film style. The filmmakers experimented with ways of rendering mental states by new uses of cinematography and editing. For example, optical devices such as irises, masks and superimpositions function as traces of character's thoughts and feelings [1.22], whilst the comparison of cinema to music encouraged the Impressionists to also explore rhythmic editing. This suggested the pace of an experience as a character feels it, moment by moment [1.23].

This film style has been identified as an apposite means for exploring the unique movable quality possessed by photochromic dyes. Therefore, the techniques used by the French Impressionist film makers will be explained in more detail in Chapter 3.

How they can then be applied practically to photochromic dyes as a way of expressing narrative will be explored in Chapter 8.

1.2.3 Colour to express emotion within narrative

As Feisner states, ‘humanity has historically represented the intangible aspects of life with tangible visualisations’, referring to symbolism and how it has employed the use of colour to impart messages about aspects of life throughout human history [1.24]. Flynn observes that it has been used as a signifier by us of, among other things, emotion. For example, we may use the colour’s name to reference a feeling or emotion, such as ‘feeling blue’ or ‘I saw red’ [1.25]. She goes on to say that on sunny days people feel happier and show more spring in their step as sunlight intensifies all of the colours that surround us, creating a more vibrant feeling. When the weather is dull and dreary, we often refer to it as a ‘grey day’, because the lack of sunlight strips the intensity of colour from objects, and causes our environment to look dull and lifeless. So when there is no light, there is no colour for the human eye to perceive which we notice when darkness falls at the end of the day [1.26].

Feisner and Flynn have also observed that, although the meanings attributed to colours differ from culture to culture, from the perspective of human being’s senses, words associated with colours from the group of reds, oranges and yellows often imply optimism, stimulation, happiness, warmth and dynamism. These are words that in themselves can be used to express a feeling of positivity, activity and energy. Words associated with the blues, purples and greys are often, but not always, related to sadness, depression, mourning and dullness [1.27] [1.28]. The words that are used to describe these negative states of mind convey slowness with regard to energy or activity. This is in contrast to the words used to describe the reds, oranges and yellows above. The colour green, which sits midway between these colours on the colour spectrum, often signifies harmony, balance, co-operation and new growth [1.29] [1.30].

The use of colour and how it has been used by painters to capture or express emotion has been researched by the following authors, among others. According to Zollinger, J.M.W. Turner was the nineteenth century painter most fluent in using colours to express an astonishingly diverse spectrum of moods. He had a fascination with light effects, particularly transient ones, as illustrated in his paintings that featured clouded skies, rainbows, snow storms, sunrises, sunsets, and smoke and fire (see Section 4.3.1),

and his work was one of the major influences on Impressionism [1.31], which has been defined as a style of artistic expression in which the creator seeks to suggest emotions, scenic mood and sensory impressions through a fleeting but vivid use of detail that is more subjective in intent than objective [1.32]. From a more recent perspective, the works of Mark Rothko and Howard Hodgkin have been observed. Diane Waldman points out that Rothko was not interested in colour for its own sake, explaining that colour was important to him as a vehicle to express basic human emotions such as tragedy, ecstasy and doom ... “the people who weep before my pictures are having the same religious experience I had when I painted them. And if you are moved only by their colour relationships, then you miss the point” [1.33]. According to Andrew Graham-Dixon, Hodgkin does not set out to paint what the world looks like but what it feels like. Whereas Cézanne painted apples, Hodgkin paints emotional situations. Hodgkin himself has said, “I paint representational pictures of emotional situations [1.34] ... and if I’ve succeeded, I’ve turned the original feeling, emotion or whatever you like to call it, into an autonomous pictorial object, which I look at in exactly the same way you do.” [1.35].

Although the intention of these artists may not have been to express narrative in the traditional sense, an image itself can powerfully tell a story. It evokes a feeling that we, as the observer, create within ourselves, have imparted to us, or a combination of both. The capacity of the works of these painters to express emotion, using colour and various techniques, will be discussed in depth in Section 4.3. The findings of that research will then be applied to explore ways that the colours and the physical movement of photochromic dyes can be used to express emotion and narrative. This will be set out in Chapter 8.

1.3 Design Examples of Narrative within Interiors

New methods for achieving visual narrative have developed and existing forms of technology are made use of in another way to achieve that aim. Unsurprisingly, the use of imagery within narration has stepped out of the storybook and cinema and onto walls and clothing.

1.3.1 Wallpapers

Wallpaper has historically consisted of a repeat design printed, or a lightly textured relief pattern embossed, onto its surface. Interactive Wallpaper [1.36], Magscapes

[1.37] (Figs. 1.1 and 1.2) and Stickyups [1.38] each give the consumer the opportunity to put their individual interpretation and expression into the application of wallpaper motifs. The placement of the motifs can be altered as they are able to be removed and re-applied, enabling the creation of a narrative that can change as frequently or infrequently as the user desires.

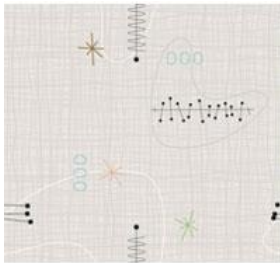


Fig. 1.1 Wallpaper magnets



Fig. 1.2 Wallpaper magnets

In Figure 1.2, the little boy may construct any story he wishes by moving the car magnets on the wallpaper. Similarly, another viewer may enter the space and, by moving just one car, create a very different story. Custom-made wallpaper and motifs allow for further self-expression.

Frames by artists Taylor and Wood [1.39] (Fig. 1.3), enable narratives to be created by painting, drawing or inserting photographs inside the wallpaper frames.



Fig. 1.3 Frames



Fig. 1.4 Heat sensitive wallpaper

In Figure 1.4, the pink flowers on the wallpaper disappear when the radiator is turned on and heat is applied, as shown in the image on the right [1.40]. The brightness of the flowers is dependent upon the temperature of the radiator. As it would be turned on in the cooler months of autumn or winter, the disappearance of the flowers would correspond with the colder weather. They would reappear with the warmer weather in spring, when the heater is not needed.

Imagery seems more realistic when it alludes to depth of space and appears to be three-dimensional (3D). Digitally and hand printed tromp l'oeil wallpapers [1.41] can be used

to re-invent a space (Fig. 1.5), or to assist someone to be transported elsewhere in their imagination.



Fig. 1.5 'Wallpaper collection'

1.3.2 Projection of imagery

We are familiar with the now more or less redundant overhead projectors, computer software presentation programmes and the medium of film. With each of these technologies an image is projected onto a screen. The ability to project imagery onto fabric and walls is also being explored in a variety of ways.



Fig. 1.6 'Virtual print' dress



Fig. 1.7 Chroma-keying

Fashion designer Hamish Morrow collaborated with image-makers to create a series of 'virtual print' dresses for his Spring/Summer 2004 show (Fig. 1.6). Models stood still as their dresses were painted with transient light patterns. Later, these 'moments' were captured and digitally printed onto a series of limited-edition dresses [1.42]. The dress is a vehicle for carrying the image of the experience the wearer has been involved with elsewhere. Additionally, the illusion of depth contained in that static image may enable it to appear as a moving image as the dress moves with its wearer. If this static image contained photochromic dyes the sense of movement and depth may be more enhanced and rhythmic as the colours developed and faded dependent on the ambient light.

Chroma keying, also known as blue-screening, is a special effects process used in movie-making and television where anything painted in a brilliant blue pigment can be digitally isolated and replaced with another image. In Figure 1.7 the blue areas within the clothing were substituted by a mountain range or the sky. The fabric, variously described as chameleon camouflage, digital cloth or a textile display, was used in a fashion show in 2002 [1.43]. Depending upon the image, this could affect the wearer's mood and interactions and depending upon the location, the narrative created by the wearer.

Optical camouflage is a kind of active camouflage where a background image is projected onto a masked object. In the case illustrated here, the coat (Fig. 1.8) becomes a projector screen for a video image of what is behind it (Fig. 1.9) tricking the viewer into thinking they can see through the person. You can observe the masked object just as if it were virtually transparent [1.44] [1.45]. In this scenario, the wearer would become the moving narrative and the story would unfold. The wearer may become like



Fig. 1.8 Masked object



Fig. 1.9 Optical camouflage



Fig. 1.10 'Insects'

a morphing being, moving between different realities, as they were visible to others then invisible, there and yet not there ... rather like the colours of photochromic dyes.

Within the interiors sector, rm* have previously created three-dimensional wallpaper and are currently working on three-dimensional stereoscopic images. The slightly shimmering image of insects was projected onto the inside of a wardrobe (Fig. 1.10) [1.46]. As well as altering the space by introducing an image into the cupboard, it alters the experience for the person opening the door and viewing the image.

Christopher Pearson collaborated with textiles and print designer Claire Canning to create an animated textile. By presenting an animated version of a static textiles print, viewers experience an alternative narrative. This perspective creates an interesting relationship with the fabric, a sort of unseen story that only exists in the mind of the viewer [1.47].

During the 1930s animators Alexander Alexeieff and his wife Claire Parker invented a push-screen frame, a board with thousands of pins embedded into it. The pins were pushed into the board at various heights, using specially shaped tools, and lighted from different angles to create shadow pictures that could be filmed one frame at a time [1.48]. Their use of pins as the main component to build up an image is reminiscent of the painting technique of pointillism where dots of colour are placed side by side, combining to create a picture.

1.3.3 Imagery involving electronics

Hussein Chalayan's LED dress (Fig. 1.11), that lit up and played its own movie, a colourful pixelated grid inspired by a cityscape, as seen from space via Google Earth [1.49], shows how we can be projecting our own custom-made story by wearing it, thus telling others about ourselves. We also then become the story. Similarly, 'Dressing Light Project', by Anke Loh, uses Lumalive technology to display full colour moving images on clothing [1.50].



Fig. 1.11 LED dress



Fig. 1.12 Tic-Tac-Textiles



Fig. 1.13 Sound reactive wallpaper

In *Tic-Tac-Textiles*, Ernevi et al discuss how computer technology and textiles have been used to create a game to be played during waiting time. It allows communication and a dialogue to occur between two people, who may be in different parts of the world, with the motifs of the game appearing and disappearing depending on the actions of the user (Fig. 1.12). The intention was to create a setting for a story to unfold during the mundane ritual of a coffee break [1.51]. The motifs used and the imagery created could be simple or more complex thus allowing for a diversity of outcomes to be generated.

Flocked wallpaper has been created that reacts to noise levels (Fig. 1.13). The louder the space, the brighter the wallpaper glows [1.52]. Whilst the flocked pattern is predetermined, the placement and brightness of the glowing is controlled by noise in the

environment. In an inverse way, someone could use sound to narrate their own silent movie.

‘Blumen’ wallpaper is able to transform a traditional decorative surface into a dynamic display of botanical life (Fig. 1.14). It divides and ornaments space and can be seen in a wallpaper format as sliding panels. By working with traditional pattern making, an ornate printed design has been created that is at the same time a working electrical circuit using electroluminescent technology. The repeating pattern allows the piece to be cut into smaller Sections and reassembled, enabling the imagery to be changed [1.53].



Fig. 1.14 ‘Blumen’ wallpaper



Fig. 1.15 ‘Digital Dawn’

‘Digital Dawn’ is a reactive window blind that digitally emulates the process of photosynthesis using printed electroluminescent technology. With a surface that is in constant flux, it grows in luminosity in response to its surroundings. The darker a space becomes the brighter the blind will glow as light sensors monitor the changing light levels of the space, triggering the growth of the foliage on the blind (Fig. 1.15). The ability and potential of fabric to flirt on the boundary of physical and virtual spaces is explored as it plays with the ethereal quality of light in a continuous dialogue with its environment [1.54].

In an article in the *Financial Times: Superior Interiors* under the title, *That’s a Beautiful Code – the latest computerized objects can be surprisingly poetic*, Emma Crichton-Miller describes ‘Six-Forty by Four-Eighty’, an interactive lighting installation by Zigelbaum + Coelho, consisting of a constellation of square coloured lights fixed onto the wall that change colour in a programmed sequence, running a gamut of cool and warm hues (Fig. 1.16) [1.55]. The installation is composed of two hundred and twenty magnetic pixel-tiles in a darkened room. Each pixel is to be touched, moved and modified. At the start of the day the pixel-tiles are packed together as a display and by the end of the day they will have migrated across the walls in the room [1.56].

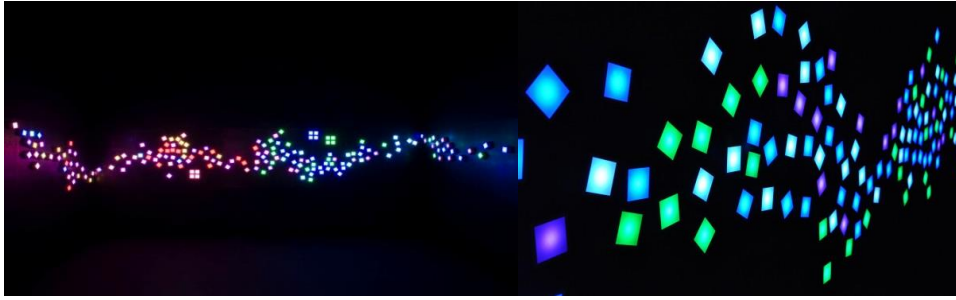


Fig. 1.16 'Sixty-Forty by Four-Eighty'

Crichton-Miller states that the installation is designed to reveal the materiality of computation by recontextualising the common pixel. The applications for this media are endless, “gather a bunch of pixel-tiles and spread them on a wall for localized illumination, paint a message for a friend or change the mood in a social space”. This installation, using computer technology, applies the principle used in Magscapes (Fig. 1.1). Again, user interaction enables a narrative to be created. Crichton-Miller goes on to say that works such as these have been described as crossing the borders between art, sociology, design and technology. In whatever sphere, digital technology has until recently tended to result in objects – from the panoply of computer hardware to computer imagery and art installations – that are self-consciously ‘techie’: hard-edged, relishing function over softer values. What is new is the desire among designers to turn these technologies to friendlier, more decorative, even domestic uses. According to Shane Walter, founder and creative director of onedotzero, “Over the past five years we have seen our audience shift from other creators to the general public. Everyone now uses computers. There is a confidence about digital technology among consumers, so it is no longer seen as alien, but as a much warmer thing ... designers are responding to this new attitude.” [1.57].

Exhibitions in public galleries such as the V&A Museum show that the above described work is becoming more accessible to the general public. For example, the exhibition ‘Decode: Digital Design Sensations’, was showing at the V&A Museum from December 2009 – April 2010. According to the website, Decode was a collaboration between the V&A and onedotzero, a contemporary arts organisation operating internationally with a remit to promote innovation across all forms of moving image and interactive arts. The exhibition explored three themes. ‘Code’ presented pieces that use computer code to create new works and looked at how code can be programmed to create constantly fluid and ever-changing works, whilst ‘Interactivity’ looked at works that are directly influenced by the viewer. Visitors were invited to interact with and

contribute to the development of the exhibits. ‘Network’ focused on works that comment on and utilise the digital traces left behind by everyday communications and looked at how advanced technologies and the internet have enabled new types of social interaction and mediums of self-expression [1.58].

The website further explains that digital technology is providing new tools for artists and designers. Innovative, often interactive, displays use generative software, animation and other responsive technologies to install a 'live' element into contemporary artworks. Some works exist in a state of perpetual evolution; others are altered by the behaviour of the spectator. From designs that draw on the barest fundamentals of code – the zeros and ones of the binary system – written by a single programmer, to art that encompasses a global collective of online creativity, many of the exhibits on display defied traditional design categories. They blur the boundaries between practices, between programming and performance, creator and participant [1.59].

1.3.4 Imagery using thermochromic dyes

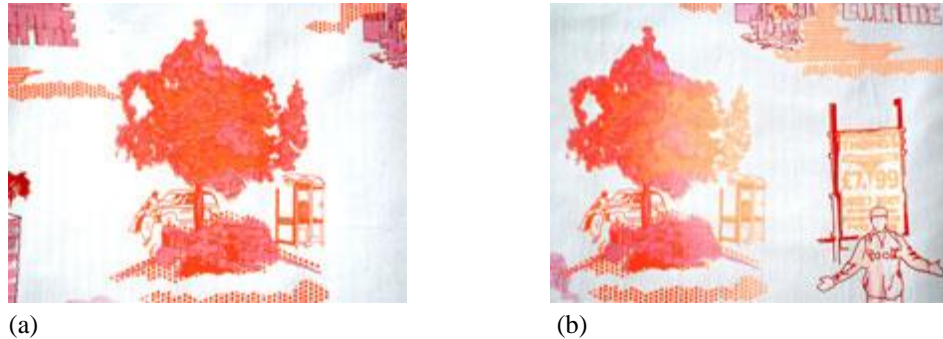
Thermochromic dyes are special effect pigments that create a temporary colour change in response to changes in temperature. When the temperature is raised the pigment changes from coloured to colourless, returning to the original colour as the pigment is cooled down [1.60]. Applications using these dyes have previously been illustrated in Figs. 1.4 and 1.12.

‘Rather boring’ tablecloth has been printed with a message that becomes visible when heat is applied (Fig. 1.17) [1.61]. As items are placed upon it, interaction may be deliberate and selective to control the appearance of messages or images, or it may be left to chance and depend upon how the meal unfolds. It may depend upon who knew what the messages/images were and where they were positioned as to the outcome of the dialogue and how the story unfolded.



Fig. 1.17 'Rather boring' tablecloth

The tablecloth could be used for specific occasions when a specific message was to be relayed and to set a particular atmosphere, or in a more relaxed and playful way that was not prescriptive. Parts of an image or text could be exposed, literally cutting up the narrative that is in place and creating another.



(a) Fig. 1.18.a Image of tree in normal mode, i.e., off (b) Fig. 1.18.b Image of tree changing, i.e., on

Carole Collet's 'Toile de Hackney' is a collection of intelligent animated textiles that depict daily scenes of Hackney in London (Figs. 1.18.a-b). Using ethnographic visual research which aims at mapping the cultural and visual characteristics of the area, a design narrative is constructed in reference to the traditional toile de Jouy, a classic design in domestic textiles. Using thermochromic dyes, the imagery gradually changes colour when switched on and reveals new hidden stories [1.62].

In *Fabrication*, Hanna Landin and Linda Worbin discuss creating dynamic, changeable patterns on textiles, looking at information technology as an active part of the fabric pattern, not only when making it but also when it is in use.

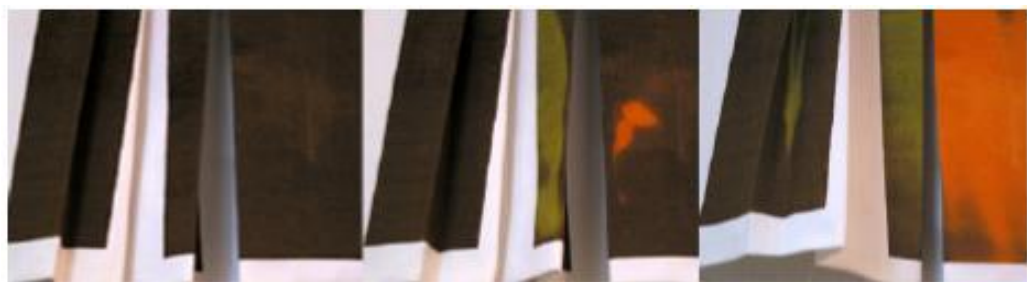


Fig. 1.19 The pattern on the apron in different sequences

Their aim is to create a pattern that changes over time, however one that is less predetermined than in other works. By using thermochromic dyes and heating elements, the pattern will be created both by the user's interaction with the actual object, in this case a bag and an apron, and by use of the information flow in the personal space (Fig. 1.19). Depending on context, situation and mood, the aesthetics will involve not

only colours and shapes, but also interaction and use [1.63]. Consequently, a more enveloping form of narrative is created.

Running Plaid is a woven textile installation created by Maggie Orth (Fig. 1.20). The artist states, “The process of creating these works is one of revelation and relinquishing of authorship. Textile panels are woven with resistive yarns, and then printed (with) thermochromic inks, which are dark and unsaturated.



Fig. 1.20 'Running Plaid'

During the printing, I am only able to imagine the colour change effect. I then connect control electronics to the textile and begin composing expressive software, which sends current to different parts of the textile, causing the resistive yarns to heat up and the fabric to change colour. It is at this point that I experience the colour change effect and see how the woven resistive yarns interact with saturated colour and software.” [1.64].

As illustrated, materials and technology in the form of, for example, light sources, dyes and electronics are being used in diverse ways to create and display imagery and to change that imagery, either directly in a controlled way or in a more relaxed and incidental manner. The complexity of the narrative varies as does user interaction. The effect of natural elements on the imagery created also varies.

1.4 Design Applications using Photochromic Dyes

Within textiles, the dyes can be either printed or extruded as a filament and woven. A diverse range of products using photochromic dyes can be seen on the website <http://www.solaractiveintl.com/index.php>. However, the ways in which the dyes are used often lends these products to having an air of gimmickry.

1.4.1 Using natural UV light – outdoors

The installation ‘Artree’ is a mannerist interpretation of a tree with the tree’s essential elements exaggerated in this experimental vision of form and function. The coating on the leaves changes colour and intensity in the presence of UV light from the sun. On



Fig. 1.21 'Artree'



Fig. 1.22 'Artree'

overcast days the leaves are nearly transparent (Fig. 1.21), whilst on sunny days the leaves will darken into an array of colours that provide shade and transmit colours to the sidewalk below (Fig. 1.22). The function of the tree's interdependence with the sun is exaggerated by drawing attention to the interplay of the leaf's reaction to light as the leaves are dependent on the sun to give them life [1.65] [1.66].

1.4.2 Using natural UV light – from indoors to outdoors



Fig. 1.23 Cloth before and after exposure to UV light



Fig. 1.24 T-shirt printed with photochromic dyes

Figures 1.23 and 1.24 show fabric, either woven or printed with photochromic dyes, before and after exposure to UV light [1.67]. An interpretation of the image and bright colours on the t-shirt may be consistent with the wearer wanting to convey that they are in a relaxed, cheerful holiday spirit. When the wearer goes out of doors parts of the image that were invisible become visible. Quite simply, some areas of the design are coloured in by the development of the dyes.

Images 1.25-1.28 show that photochromic dyes are increasingly being experimented with and slowly moving into mainstream women's fashion, being used on items such as dresses and swimwear. The dress in Figure 1.25 remains white indoors, however a yellow geometric print appears once the model steps outside [1.68]. Like the t-shirt, when the model moves indoors the design would fade and revert to its colourless state.

On both pieces of clothing, the design is predetermined and cannot be changed other than varying in degrees of visibility. The purpose of these two designs may be purely for novelty value.



Fig. 1.25 Geometric print dress



Fig. 1.26 Petal dress

Amy Winters, a Central St Martin's new media artist and fashion designer, presented a Spring/Summer 2011 ready-to-wear collection at London Fashion week in September 2010 (Figs. 1.26 and 1.27) [1.69]. The dress on the left in Figure 1.26, a short-sleeved



Fig. 1.27 Orange lightning print panelled dress in taffeta



Fig. 1.28 'Now you see it, Now you don't' UV sensitive skirt

stretch-cotton light pink mini-dress is screen printed with sun-reactive ink. Indoors the dress remains pink whilst sunlight transforms the dress colour as shown on the right. Likewise, the panels in the dress in Figure 1.27 reveal a purple dotted pattern in sunlight [1.70]. Using bespoke prints with hydrochromic and photochromic inks, the collection was inspired by the vibrant colour of the rainforest, light rain, cloud bursts and tropical thunderstorms. Printed rainbow hues are lavished onto simply cut garments. The clothes become multi-dimensional as the prints interact with the elements changing colour and pattern [1.71]. Winters explained what inspired her to combine fashion and

science, “I studied theatre design at college and have been always interested in creating imaginary worlds through costume and set. Seemingly ‘unusual’ combinations of expertise and methodologies produced unexpected results and also allowed me to create something multi-faceted and more interesting for an audience.” [1.72].

The designer of the fashion collection, ‘Now you see it, Now you don’t’ (Fig. 1.28), Dilusha Rajapakse, addresses issues of body image, saying that the media revolution has resulted in women being bombarded with myths about femininity and the feminine ‘image’. She states, “In a society where men stare at women, making decisions on the basis of visual impressions, women who don’t have a perfect body need an alternative.” Humans change clothes so that their ‘identity’ can be appropriate for each new situation. “Pretending to be someone else or being invisible would be an advantage to avoid insecurity ... camouflaging and deceiving someone’s sight or wearable animated surfaces could be used as a meaning (sic) of generating a positive self image. The concept of ‘Now you see it, Now you don’t’ is an approach to conceal and strengthen this sort of woman.” [1.73].

1.4.3 Using natural UV light - indoors

Initially, when architects began to think about smart windows in the late 1980’s, their desire was to create a glazing material that responded directly to environmental changes. Photochromic materials had been developed for eyeglasses in which the lens darkened as the incident light increased. This seamlessness in response appealed to building designers, who thought that covering the glazed facades of buildings would provide not only moderation of daylight, but would also help prevent unwanted transmission of solar radiation. Sunglasses, however, had to address only one condition, that of light incident on the outside of the lens, whereas buildings need to deal with multiple situations, particularly those produced by large swings in exterior temperatures [1.74].

The windows in Figure 1.29 have been painted with UV-sensitive ink so the graphics appear translucent white at night and turn bright blue when a ray of sunlight hits them in the morning [1.75]. They could serve as decoration and function as a window covering for privacy whilst letting the light in during the day. The brightness of the image may be used as an indicator of the strength of the sun or as a simplistic indicator of the time of day. Weather conditions affect the image and the messages that it is able to relay.



Fig. 1.29 Colour changing window stencils

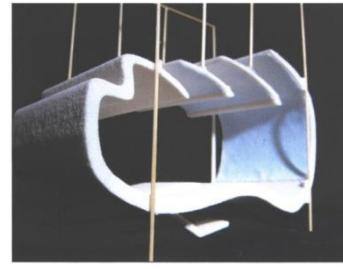


Fig. 1.30 'Coolhouse'

'Coolhouse', made by architecture students, shows experimentation with how photochromic dyes may be used in interiors. Interior panels are covered with photochromic cloth which changes from a base colour of white to blue upon exposure to sunlight (Fig. 1.30). The panel shapes are designed for a particular solar angle for a specified time and place during the summer. At this time, the interior becomes a cool blue. However, in the winter the cloth is not exposed and the interior remains white [1.76].



Fig. 1.31 'Golden Bough'

In *Fabrication*, the authors, Landin and Worbin, point out that most textiles in our surroundings have a static pattern, like 'Golden Bough' (Fig. 1.31). A fabric is designed with one pattern that is more or less permanent; it does not change its appearance, except for tearing or stains that may occur. A static pattern is produced either by weaving or knitting or by textile printing. Conversely, a dynamic pattern is a non-static pattern that changes with respect to context of use. For example, the fabric in Figure 1.32 is made out of photochromic treated threads enabling the curtain to change colour from white to coloured when the sun rises, creating a dynamic pattern that can react upon existing information in the surroundings. However, the pattern is still designed before weaving with one pattern designed for when the textile is exposed to UV light and another pattern for when it is not. Therefore, it is a dynamic pattern in the sense that the fabric can change its pattern, but it can only shift between two static ones [1.77]. There has been little exploration into the extent to which these dyes are able to

create moving imagery, thereby pushing the boundaries of our perception of what they can actively achieve.



Fig. 1.32 'Information curtain': before and after exposure to UV light

The light-sensitive wallpaper in Figure 1.33 apparently displays a morphing pattern created by shadows from ordinary objects [1.78]. Its imagery is determined by the amount of available sunlight and other environmental conditions, natural and man-made. 'Appearing-pattern' wallpaper (Fig. 1.34), comes in a solid colour when purchased, but a

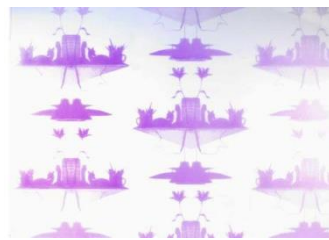


Fig. 1.33 Light-sensitive wallpaper



Fig. 1.34 'Appearing pattern' wallpaper

pattern emerges over time, perhaps several years, as sunlight exposes textures printed with UV-sensitive ink. The placement of curtains and furniture affects the patterns that unfold [1.79].

Kathy Schicker uses photochromic dyes to create a range of products for interiors including backdrops, cushions and upholstery fabrics that constantly respond to the natural environment, interacting with the changing light of the days and seasons [1.80].

1.4.4 Using artificial UV light

Holmquist and Melin discuss how they would like to use computer graphics with textiles to 'find new materials and modalities to display computer-generated information and images', in their paper *Using Color-Changing Textiles as a Computer Graphics Display*. After initially weaving a fabric, using photochromic threads, that is white at night then becomes colourful during the day when exposed to natural UV light, a device has been constructed using a UV lamp to reveal hidden patterns (Fig. 1.35). The intention is to be able to selectively turn the fabric's colour on and off like computer

pixels to construct displays that are calmer or more ambient than traditional computer displays by, for example, creating displays in the form of draperies or tapestries (Fig. 1.36) [1.81]. Therefore, Holmquist is attempting to use photochromic material to create



Fig. 1.35 Dyes developed by UV lamp



Fig. 1.36 Colour-changing textiles

a narrative between computer users so that they would be able to control the appearance and disappearance of messages.

1.5 Summary

The illustrations given show that as technologies develop, they are adapted and used creatively in new applications within the field of design. These examples show how various technologies are being used to change imagery. The movement of the image varies as does the extent of the change of image and user interaction. They also express visual narrative to a greater or lesser degree. Correspondingly, the definition of narrative appears to have broadened, expanding from the more traditional and simplistic to encompass a changing landscape where new forms of imagery and communication are being created.

Design application with photochromic dyes has thus far been basic, predominantly exploring the medium as it is exposed to natural UV light. Preliminary work with artificial UV light sources, see Figures 1.35 and 1.36, shows how the development of the dyes, and the subsequent image, can be controlled. By harnessing the singular qualities of these dyes and the interactions of their colours with one another, this research aims to successfully evoke a particular atmosphere so that, as previously stated, something not immediately or materially apparent will be brought out, evoked or led forth [1.82].

The stylistic techniques that have been utilised within French Impressionist films will enable the practical capabilities of the dyes to be ascertained when they are applied to the textile substrate, and serve as a guide for the development of subsequent design work. They will also be explored for their use as a means of assisting with the expression of feelings and the consequent creation of a narrative.

Research into the use of colour with regard to emotions will inform the choice of, and its placement within, images, motifs or patterns. This will then need to be combined with the movement of the dyes. The resulting visual effects that the dyes create and how they interact together, with both colour and movement, will decide their suitability as a means for conveying a sense of changing atmosphere with the intention of expressing a form of narrative. It would also be then that any new dialogue about this work would present itself and could be discussed.

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Chapter 2

Methodology

Methodology

2.1 Aim

The aim of the project is an investigation into achieving visual narration using photochromic dyes on a textile substrate. This research will be facilitated by exploring the ability of the dyes' colours to capture emotions ranging from joy to sadness and, in so doing, establish the parameters of their movement.

I realised from the beginning of this project that my ideas for the outcome may be conceptual. It was not assured that the dyes would be able to perform to meet the defined aim of this research in their current state, as they were not developed for use in this way or indeed for use on textiles, as they were optimised for ophthalmic applications [2.1]. However, according to Krippendorff,

‘Inquiries that could inform design practices would have to start by acknowledging the simple fact that design is concerned with how we may want to live in future worlds ... Whereas science concerns conceptions that worked so far, design concerns what could work in the future, a future that is more interesting than what we know today. A design is always a proposal, a conjecture. Whether it delivers what it promises, whether it will work in the foreseeable future, cannot be known until it ceases to be a design and becomes part of its users' history.’ [2.2].

It was also my intention that the exploration of the dyes' behaviour, on route to achieving the stated aim and objectives, would establish guidelines of their limitations when developed by artificial UV light in a controlled manner. This knowledge could then enable the dyes to be used in selected practical applications, and inform and encourage technological research for use in future design and technological projects.

2.2 Objectives

The practical testing of the dyes was carried out whilst the stylistic techniques of the French Impressionist films and the artists' and designers' use of colour was researched. The following objectives guided the initial testing of the dyes and the theoretical research:

1. Initial printing of the dyes will assist with establishing familiarity with the practicalities of working with this medium (which differs in that the dyes cannot be seen until exposed to UV light, upon which the colours become visible), and with answering

simple design questions. A more specific methodical system of testing will then be developed to answer specific questions.

- Print a selection of **basic designs** to answer simple design questions. Observe and note/tabulate/compare the differences.

A selection of simple designs in single colours to be printed on a range of fabric substrates to gain an understanding of the practicalities of working with these dyes, and to observe the appearance of the colours as they develop in sunlight and fade.

The word appearance is used when referring to the visual presentation of the dyes, for example, their colour, as opposed to the action of their development.

- Ascertain on which **fabric substrate** the colours of printed photochromic dyes develop most strongly and consistently across the palette to enable use of a full colour range. Observe and note/tabulate/compare the differences.

The dyes to be printed on a wide selection of natural and synthetic fibre fabric substrates and observations regarding colour and substrate suitability for end use made. The choice of substrate will initially be based on the resulting strength of the developed colours. The appearance of the substrate from the point of view of the observer will later be considered. As the 'screen' will essentially be a textile, the visual textural appearance of the fabric will be considered.

- Observe the **appearance and the development of the colours** of the dyes when they are used in combination. Observe and note/tabulate/compare the differences.

Print a range of simple designs incorporating several colours to observe the visual effects of the dyes' colours, their resulting hue and intensity. Observe the effect of undeveloped colour within the print, and of placement and proportion of colour within a design. Mix the dyes to create another colour and observe the resulting visual effect within a design. Observe the time taken for the dyes to develop and fade in relation to one another.

Print a variety of basic designs to observe the resulting colour of, and the effect created by the movement of, photochromic dyes when they are printed on top of, and beside one another, and when photochromic dyes are printed on top of, and beside, pigments. Observe plain printed samples of the dye colours as they fade, after being developed by sunlight, to establish their fading order.

Print sample squares of photochromic dyes, one on top of the other, and observe the resulting colours and fade back effect. Mix photochromic dyes before printing and observe the resulting colours and fade back. A baseline guide to the colours of mixed dyes will then be available for use.

- Evaluate the effect alternative **textile surface qualities** have on the appearance of photochromic dyes.

Print the dyes on sateen for a smooth filmic surface quality, apply the devoré process for added dimension, and prefelt for added texture and a grainy appearance. Evaluate these effects and their suitability for use within this project.

- Observe the colours of the dyes when they are **extruded** in polypropylene.

The dyes to be extruded in polypropylene, developed in sunlight and their colours and fading order observed.

- Evaluate the development of the dyes by **artificial UV light**.

Observations for hue and intensity of colour to be made of the dyes when they are developed under 365nm light tubes as this is the optimum wavelength for their development [2.3].

- Ascertain the **development and fade rates** of printed and extruded photochromic dyes using artificial UV light. Observe and note/tabulate/compare the time differences.

The printed and extruded dyes to be developed by both 400nm and 370nm LEDs at a range of currents and exposure times to determine whether the fade rate of each of the dyes is affected by

- 1. the amount of time the dyes are exposed to the UV light source*
- 2. the strength of the current that applies the UV light to the dyes*

The developed dyes will also be observed for their hue and the marks they make on the substrate.

- Observe the development of both printed and extruded dyes by **fluorescent light** as the design product will be placed in an interiors setting.

2. Imagery, colours and ways of mark making that would effectively demonstrate a change from one colour/image to another will be explored.

- Consider and identify the colour/imagery that shows the potential for changing from one colour/image to another.

Collect relevant images that represent movement and a change in colour.

- Explore ways of mark making that would effectively use the photochromic colours to show a change in colour/image.

Experiment with different ways of mark making. Collect imagery that illustrates marks that may be appropriate for building designs.

3. French Impressionist films are useful as a starting point and an inspiration for this research project in two ways. The stylistic techniques that have been utilised within the films, as a visual means to assist with the expression of feelings, will be mimicked by the photochromic dyes as they are applied to the textile substrate, with the intention of being used, in part, as a way of conveying feelings or emotion. However, additionally, and perhaps more importantly, the stylistic techniques will be useful from a practical perspective for exploring the technical ability of the dyes. The ability of the dyes to move, the scope for controlling their pace of movement and the extent to which they can be manoeuvred will be explored. The success and suitability of utilising the dyes within a larger design scenario will then be evaluated.

- Define and then decide the **techniques** of French Impressionist films that are to be explored and potentially replicated using photochromic dyes on a textile substrate.

Theoretical research of French Impressionist films will give an understanding of the background to these very subjective films and explanations behind the use of the stylistic techniques. This will be followed by the practical observation and analysis of the films, frame by frame, to observe the techniques used. Sketch the stylistic techniques in a storyboard sequence. Those techniques to be used to explore the movability of photochromic dyes will be selected by considering their actions on the film screen and their potential for replication by the dyes on fabric.

4. The inherent colours of photochromic dyes and how they can be used **to express emotion** on a textile substrate will be explored within this project.

- Research the use of **colour and its application** by eminent painters and contemporary textile artists/designers, for whom the expression of emotion is a fundamental part of their work.

Paintings by Turner, the French Impressionists, Rothko and Hodgkin to be researched and analysed, for the artists' use of colour, motif, proportion and placement, among others. Primary research in the form of field visits to

exhibitions and galleries, and firsthand discussions with textile artists, will also be carried out. Collate the information gathered and establish the colours to be used.

The following objectives guided light source development, recording and presentation of outputs:

5. Based on the results of the UV LED testing, the building of a UV LED array will be carried out in a step-by-step process. Its suitability for developing the dyes to explore the project aim can then be established.

- Arrange for the **construction** of a UV LED array on which the intensity of current to be sent to the lights and the amount of time the lights are to be switched on are both able to be controlled by the user.

*Work closely with **hardware engineers** so that a small LED array is built that gives the user the ability to control both the intensity of current that is sent to the lights and the time frame with which the lights develop the dyes.*

6. The results of tests using this array will be considered and a larger array that is computer programmable will be built, based on requirements from a design perspective.

- Establish what is needed from a larger and computer programmable array and arrange for its construction, so that the design aim can be further explored.

Work closely with hardware engineers so that a computer programmable array, on which the intensity of current sent to the LEDs and the time frame within which they develop the dyes, will be able to be controlled by the user.

- Establish the most effective way to use the **computer programmable array** so that greater fluidity of movement will be given to the colours of the dyes, as well as independence to the designer.

*By working closely with a **software engineer**, software will be written to control and vary the strength of current to be run through the LEDs, and control and vary the amount of time that the LEDs emit a particular strength of UV light. Learn to write the text data that will drive the LED display for the development of the dyes, and to facilitate greater independence and greater scope for design development.*

7. Due to the ephemeral nature of the dyes, a means of recording and viewing design development work will be needed.

- Establish the most effective way to **record** design tests and development work.

Explore ways of recording the movement of the dyes, by filming, to facilitate their observation and assist with the subsequent generation of design ideas.

- Establish the most effective way to **present** the design tests and development work.

Explore means of presenting the films that will enable design test and development work to be viewed in an enlarged format and so that the visualisation of the design concept can be shown.

The following objectives guided the testing of dye development using UV light sources:

8. A way of using the small LED array will need to be established so that the appearance and fading of the dyes when developed in this way is able to be understood.

- Ascertain the effectiveness of using a **platform of LEDs** for developing the dyes by observing the dyes' appearance and fading when developed by the small array.

Use the whole array to develop individual dyes, a combination of dyes, and mixed dyes for their appearance and fading patterns. Develop the dyes with a series of light patterns and observe their appearance and fading patterns. Observe the interactions of the light sources and the dyes. Observe the appearance and fading of the dyes when developed by different strengths of current.

9. A way of using the larger and computer programmable array to develop the dyes, by combining its features with the dyes' movable quality, will need to be established.

- Ascertain the most effective way to use the **computer programmable array**, in conjunction with the printed dyes, to create design work.

Based on results from the tests on the small array and looking towards the design aim, develop selected dyes using selected light patterns whilst varying the time the dyes are developed and the strengths of current used.

The following objective guided the development of the dyes to **create designs** that illustrate the effects that have the **potential for creating visual narrative**:

10. Ascertain the techniques that show the potential for creating a form of visual narrative.

- Identify the most appropriate **methodology** for using these dyes to create designs.

- Define the **film techniques** that show the most potential for conveying a sense of narrative using these dyes.

Isolate, by sketching, the techniques that show the potential for creating narrative sequences.

- Explore **design sequences** using the **narrative effects** identified in the design tests and visual research.

Sketch sequences to illustrate the movement of the dyes and changes in the colours that appear on the substrate. Research ways that colours move, both within nature and man-made, noting the effects they create as they change and how these could be re-created using the dyes.

- Explore ways of **combining** the **narrative effects** identified in the design tests with the previously isolated **film techniques**.

Plan simple design sequences by sketching. Explore/consider the style of imagery to use. Plan the relevant light patterns. Write the appropriate binary code. Develop the dyes and observe the results. Record the sequences using photography and/or film. Based on the results of each development, alter the sequences, imagery and/or the timings used. Continue with this iterative process until effective techniques have been isolated and used together to illustrate the potential of these dyes to create a visual narrative.

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Chapter 3

French Impressionist Films

French Impressionist Films

3.1 Introduction

The stylistic techniques of French Impressionist films presented as a potentially very appropriate template for the sequencing of the development of photochromic dyes. The effects created by these techniques, as frames moved from one scene to the next, were analysed to observe the use of black and white, and shadow and light, so that the techniques could be emulated by the dyes.

3.2 French Impressionist Films as a Means of Exploring the Dyes

As mentioned in the literature review, the decision to use the stylistic techniques of the silent French Impressionist films within this project was two-fold. Firstly, a French Impressionist film is a very subjective story of the individual. These very subjective films elicit emotions, with the maker having a very clear idea of what he wanted the viewer to experience. The stylistic techniques employed had a narrative function, with the story being told determining the devices used [3.1]. Secondly, as these devices were used to show imagery emerging into view and/or fading from the screen, they also provided predetermined patterns that would be a useful starting point for the exploration of the movement of the dyes.

Examples of stylistic techniques are shown below. Figure 3.1 shows the iris technique, a form of masking, as it progressively focuses in on part of a scene. This technique can also have soft edges, as in Figure 3.2.



Fig. 3.1 La Roue (Gance, 1922)



Fig. 3.2 J'Accuse (Gance, 1919)



Fig. 3.3 J'Accuse (Gance, 1919) Fig. 3.4 La Dixième Symphonie (Gance, 1918)

Figure 3.3 shows superimposition and Figure 3.4 is an example of side lighting.

French Impressionist films were in black and white. This stark contrast enabled the effective and dramatic use of shadow and light to create imagery within scenes and to convey a range of feelings from the dramatic to the more subtle, e.g., love, happiness, anger and despair.

Photochromic dyes are available in a range of colours that could be used to achieve a similar effect, whilst also adding another dimension to what would ordinarily be a flat, stationary print. The objective is to evoke feeling within the viewer by the movement of the colours, drawing on colour's relationship with emotion, as the dyes appear and disappear. As the dyes behave differently in varying degrees from one another, the resulting visual outcomes as they mimic the stylistic techniques will be used to inform the content of the design development as it progresses.

3.3 Analysis of Stylistic Techniques

A list of French Impressionist films was compiled by searching the internet, making telephone calls and emailing local, national and international film organisations, and universities. The British Film Institute in London and the Cinémathèque Française in Paris held originals or copies of some of the films, however they could only be viewed by visiting the institutions. Knowing they would need to be viewed repeatedly, I searched for copies that I could buy. Both *El Dorado* (1921) by Marcel L'Herbier and *Coeur Fidèle* (1923) by Jean Epstein were available in DVD format on French Amazon. *El Dorado* is a melodramatic story about a mother, her ill son, rejection, despair, young love, hope, retaliation and suicide. *Coeur Fidèle*, also a melodrama, tells of love, despair, deception, apathy and violence.

Using a DVD player enabled the films to be stopped, rewound and replayed as necessary, allowing them to be viewed frame by frame so that the stylistic techniques

could be sketched out in pencil and analysed. This step-by-step approach also enabled the observation of how shadow and light was positioned within each scene and moved from frame to frame. It would also be useful for the step-by-step planning of the development and fading of the dyes within designs.

The thesis entitled *French Impressionist Cinema: Film Culture, Film Theory, and Film Style*, by prominent American film theorist, film critic and author, David Bordwell [3.2] [3.3], has been relied upon heavily for informing my understanding of French Impressionist films and the subsequent information provided herein.

Below is a list of the stylistic techniques observed in the two films. As it became apparent that certain techniques were repeatedly used, either in the same way or as a differing version of the same technique, the list was divided into groups based on the effects and activity in the scenes as follows:

- slow emergence or fading of an image or scene
 - dissolve (to another image)
 - superimposition (an optical technique in which two or more shots appear within the same frame, one on top of the other)
 - end of film (split screen effect, close-up and fade out)
- use of blocks of black or white to move from one scene to another
 - end of film (split screen effect, close-up and fade out)
 - wipes, fade outs/fade ins
 - iris technique
- blurring/lack of definition of an image
 - soft focus
 - gauzily blurred
- focusing in on an image
 - close-up (from one perspective to another)
 - techniques of masks (these were used to mark a character off for attention, such as irises)
 - end of film (split screen effect, close-up and fade out)
- contrasting use of black and white
 - back lighting/side lighting
 - shadows (which allude to off screen space)

- extreme lighting situations (shimmering light on water).
- speed of the movement in the scenes
 - slow motion/fast motion [3.4]

These groupings would prove helpful when organising the testing of the dyes, as well as their placement within the overall design sequence.

A broad outline of the stylistic techniques is given below. It should be noted that they are being explained here with regard to how they may be used within this project as the physical capabilities of photochromic dyes are explored. Although discussions of the techniques are most often made with reference to characters, they are to be applied to the pictorial or abstract imagery that will be explored and created within this project.

3.3.1 Optical devices

Optical devices are distortions or manipulations of the surface of the film image. They are used to function as traces of characters' thoughts and feelings [3.5], and include masks, dissolves, superimpositions, focusing, irises, wipes, fade ins and outs, as well as the distortions created by the use of slow and fast motion. Irises, dissolves, wipes and fade ins and outs are standard transitions usually marking ends and beginnings of scenes. For example, the split screen effect may be used or, as with the close-up of the lovers at the end of *Coeur Fidèle*, the motto 'Toujours Fidele' that they had scrawled on a building is superimposed over the image. At the end of *El Dorado*, the crowd around Sibella slowly fades, title words appear and then her body fades out, disappearing from the screen. Various masks and framing devices are used to mark a character off for special attention. For example, irises may concentrate attention on a face, a gesture or an object [3.6].

The emphasis on personal emotion gives the films' narratives an intensely psychological focus [3.7]. However, the devices may also be used to indicate physiological states like blindness, drunkenness or delirium. For example, part of a shot that is gauzily blurred comes into sharp focus suggesting a change of mood. Blindness may be shown by a blurring close-up or a weeping thief may see a magistrate as a blurry shape. Memory and fantasy can be displayed by gauzy focus, superimposition and dissolves or fade ins. Time is also sometimes abridged by means of dissolves and changes in focus.

Optical effects were also included for purely decorative purposes. For example, a white arch-shaped mask around a garden party, gauzy focus in certain scenes and slow superimpositions serve to simply make interesting images [3.8].

3.3.2 *Close - up*

The close-ups in Impressionist films are frequently concentrated on parts of bodies and objects. As a result they may embody in an object a dramatic, thematic or abstractly conceptual meaning. Alternatively, combining close-ups of dramatically significant objects can be used to express a character's train of thought. They are also often used to represent a character's optical point of view, as, for example, shots repetitively become closer and closer [3.9].

3.3.3 *Editing*

Bordwell and Thompson describe how the comparison of cinema to music encouraged the Impressionists to explore rhythmic editing as a way of suggesting the pace of an experience as a character feels it, moment by moment. During scenes of emotional turmoil or violence, the rhythm accelerates - the shots get shorter and shorter building to a climax, sometimes with shots only a few frames long [3.10]. This is especially common in scenes of extreme physical action. The rhythm of the editing also tends to suggest the experience of great speed, created by accelerated cutting [3.11], and slow motion is used to emphasise certain actions [3.12].

Instances of glance/object editing range from the very simple to the quite complex as this editing pattern permits inanimate objects to be integrated into a drama: the act of looking endows objects with dramatic significance. Powerful emotions can be expressed through the economical means of simply alternating viewpoint shots and reaction shots; no words and very few gestures are necessary [3.13].

3.3.4 *Lighting and shadows*

Impressionist films sought out a range of extreme lighting situations, with a great degree of experimentation given to the angle and position of a single light source. An example of this is side-lighting - a single strong light source from the side, see Figure 3.4. Another lighting phenomenon extensively used is shadows [3.14].

Although light sources as such will not be used within the designs in the way they are used within the films, the dramatic effect that darkness against light achieves will be explored with colour.

3.4 Summary

The stylistic techniques observed and analysed in the two French Impressionist films, and set out in Section 3.3, provide a range of ways for exploring the technical abilities of photochromic dyes. The extent to which the narrative purpose of the techniques will be able to be translated, and utilised by the rather different medium of photochromic dyes, as they are applied to a textile substrate, will also be examined.

3.5 References

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Chapter 4

Colour

Colour

4.1 Introduction

This project is based on the actions of the colours produced by photochromic dyes and the way they can be utilised within textile design as they develop, fade and disappear. It is this combination of the colour that a dye wears and its movement that will be explored. The speed of movement of the dyes varies, with a particular colour of dye being attached to a certain speed. Just as the medium, the teller (creator) and the narrative are inextricably dependent on one another (Section 1.2.1) these two characteristics of the dyes are also inseparably interlinked.

Painters have successfully used the mediums of oil or watercolour, on canvas or paper, to express themselves or capture the essence of a place, circumstance or event. Likewise, textile artists either apply colour to the fabric substrate or use coloured fabric and threads, among other things, in combination to create an artefact that captures and conveys a particular feeling. Therefore, the work of prominent artists from both disciplines has been researched to gain an understanding of their use of colour to capture or express emotion using these mediums. This information will then be used as a reference to guide my decision making in the process of design development.

4.2 Colour

Colour is defined as an attribute of things that results from the light they reflect, transmit or emit in so far as this light causes a visual sensation that depends on its wavelengths [4.1]. We see these visible light waves, the only electromagnetic waves we can see, as the colours of the rainbow with each colour corresponding to a different wavelength of the electromagnetic spectrum. Red has the longest wavelength and violet

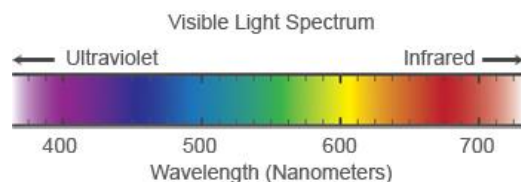


Fig. 4.1 Spectrum of ultraviolet and visible light [4.2]

has the shortest wavelength (Fig. 4.1) [4.3]. The term ultraviolet means ‘beyond violet’, from the Latin *ultra*, which means beyond [4.4]. Therefore, ultraviolet light is electromagnetic radiation with a wavelength shorter than that of visible light, in the

range 10nm to 400nm [4.5]. It is ultraviolet light in the range of 350nm – 410nm that is preferably used to develop photochromic dyes [4.6].

Within the visible spectrum, the primary colours, red, yellow and blue, contain no trace of any colour other than their own and cannot be mixed from another colour. The secondary colours, green, purple and orange, are mixed from colours that lie either side of each of those colours on the colour wheel (given to us by the German scientist Goethe [4.7]) as illustrated in Figure 4.2. For example, green is mixed from yellow and blue, purple from red and blue, and orange from red and yellow. The colour wheel can be extended further by continuing to mix colours in this way, introducing tertiary colours, and so on. Although the colours of photochromic dyes are not ‘pure’ as such, they will be mixed to observe the resulting colours, and subsequently experimented with to see if the combinations of their colours and their fade rates can be used to create effective visual interactions.

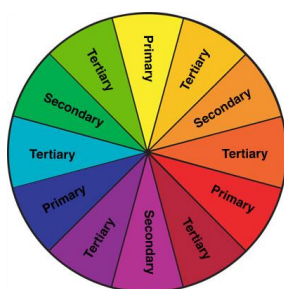


Fig. 4.2 Goethe's colour wheel

Much has been written about the various ways colour has been used by man within art and design. The Greeks and Romans are famous for their classical architecture and design, but they were also lovers of vibrant colours and developed methods of decoration that we still use today. The Romans created wall murals known as trompe l'oeil (a visual illusion in art, especially as used to trick the eye into perceiving a painted detail as a three-dimensional object) [4.8] and had mosaic floors and walls, all often vivid in colour [4.9]. As shown in Figure 1.5 on page 10, trompe l'oeil is used within contemporary design applications. This technique has the potential to be used successfully with photochromic dyes as it is anticipated that their inherent quality may enable three dimensional effects to be created when mimicking the trompe l'oeil style.

4.3 Painters

The work of Turner, the French Impressionists, Rothko and Hodgkin has been studied to gain an understanding of what guided these artists in their use of colour, whether they used motif or abstraction, if paint was layered or used as a wash, the marks made on the substrate, and the placement and scale of colour on the canvas.

4.3.1 J. M. W Turner

According to Wilkinson, colour interested Turner less than light and shade, the geometries of composition, movement, contrast, wind and weather, the nature of land and sea, the pathos of man, the pervasive glow of classical sunsets, the play of summer light on the willows of his favourite Thames, the shapes of boats and, always, the patterns of clouds [4.10]. However, colour still needed to be understood for those themes to be successfully depicted by the artist. Therefore, Turner's work is an appropriate source of reference for this project.

A sampling of the descriptions of the colours used to describe Turner's paintings was gathered from Martin Butlin's *Watercolours* and Tate Gallery's *The Turner Collection in the Clore Gallery*. These descriptions can be divided into two groups: blue, deep blue, blues and blacks, grey, greyish-blues and pinks, grey and brown, green, greenish-browns, blacks and pinks *and* strong oranges, red, warm reds and yellows, brilliant range of reds and yellows, radiance of red, yellow and blue, scarlet and gold, flaming and rosy.

This dichotomy, however, does not necessarily reflect Turner's use of certain groups of colours to depict particular atmospheres, i.e., an atmosphere is not necessarily achieved by drawing from one set of colours over another. For example, pale blues, pinks and yellows show the calmness of 'Lake Lucerne: the Bay of Uri from above Brunnen' (Fig. 4.3), whilst the same colours are used to illustrate drama and frenzy in 'A Tree in a Storm' (Fig. 4.4).



Fig. 43 'Lake Lucerne: the Bay of Uri from above Brunnen', 1842



Fig. 44 'A Tree in a Storm – Watercolour', c.1820-30

'The Evening Star' (Fig. 4.5) is so tranquil a scene, so concerted a harmony between sky, sea and shore [4.11], whilst 'Snow Storm' (Fig. 4.6), using similar colours in different proportions, shows nature wreaking vigorous destruction [4.12]. The speed of the train (Fig. 4.7) contrasts with the stillness of 'Morning, returning from the ball, St. Martino' (Fig. 4.8).



Fig. 4.5 'The Evening Star', c.1830



Fig. 4.6 'Snow Storm', 1842



Fig. 4.7 'Rain, Steam and Speed - the Great Western Railway', 1844



Fig. 4.8 'Morning, returning from the ball, St. Martino', 1845



Fig. 4.9 'Lakeview, Moonlight', c.1835-6



Fig. 4.10 'Storm at Venice', c.1835

The serenity of 'Lakeview, Moonlight' (Fig. 4.9) contrasts with 'Storm at Venice' (Fig. 4.10).

Butlin commented on 'Venice from Fusina' (Fig. 4.11) as an almost abstract essay in pure colour, arranged in three bands, the lowest, the lagoon, in no way reflecting the sunset tints of the sky. It seems to have been developed over the even simpler groundwork of a blue wash at the bottom, later painted over with green to represent water, and a pink one at the top, partly covered with the warm reds and yellows of the middle zone [4.13]. He also described 'Venice: The Guidecca from the Lagoons' (Fig. 4.12) saying the forms are ethereal, being suggested by tonal variations, assisted here and there by pen or brush-strokes, mainly in red, but also in blue and other colours [4.14].



Fig. 4.11 'Venice from Fusina', c.1835



Fig. 4.12 'Venice: The Guidecca from the Lagoons', c.1840

According to Gage, yellow was Turner's favourite colour and it became the hallmark, almost the objective, of his art as a colourist, 'for pictures wanted colour' [4.15]. He also had a preoccupation with clean, unmuddied colours [4.16], and seems to have learned a heightened capacity to use pale but brilliant and delicately balanced masses of colour without dark shadow (Figs. 4.13 and 4.14) [4.17].



Fig. 4.13 'Norham Castle', c.1845-50



Fig. 4.14 'Sunrise with sea monsters', c.1845



Fig. 4.15 'Shade and Darkness - the Evening of the Deluge', 1843



Fig. 4.16 'Light and colour (Goethe's Theory) - the morning after the Deluge - Moses writing the book of Genesis', 1843

In *The Turner Collection in the Clore Gallery* it states, 'The reference to Goethe reminds us of the German author's proposal that colours carry with them emotional connotations, varying from joy to despair, corresponding to their respective warmth or coolness; and indeed the two works exploit the contrasts of cold and hot, dark and light, horror and exaltation with a theatrical force that seems to sum up the whole range of Turner's art.' 'Shade and darkness - the evening of the Deluge' (Fig. 4.15) exploits a palette of blue, grey and brown while this triumphant burst of light, i.e., 'Light and colour (Goethe's Theory)', announcing God's Covenant with Man after the flood (Fig. 4.16) is couched in a brilliant range of reds and yellows [4.18]. Such a broad gamut of emotional reference was always a vital feature of Turner's work and most pronounced in his later canvases [4.19].

According to Gage, Turner was less and less concerned to express chromatic harmony, but rather the conflict of light and dark [4.20], his preoccupation with colour and light characteristic of the second half of his career [4.21]. The often repeated theme of the triumph of light over darkness reflected the steady progress of his own art from the sombre tonality of his early work to the luminous brilliance of his last canvases [4.22], with his use of colour becoming increasingly conceptual towards the end of his career [4.23].

The recurrent themes in Turner's work are of clouds and light, either moonlight or sunlight, and water. Many of Turner's works depict a circular motion. This may be a vortex-like [4.24] depiction of cloud shown in the middle of the sky (Figs. 4.6, 4.7, 4.15 and 4.16). Washes are used to create streaks and wisps of cloud which 'were mixed very wet, in contrast to the blue washes of more usual consistency used for the sky' [4.25]. Some forms 'are modelled in solid flat washes' whilst others are 'suggested by a

much more open technique in which the brown ground is left bare between blue and white brush-strokes and heavily dragged washes of white' [4.26]. Other sketches are richer in colour, sometimes in strong oranges, similarly worked with a wet brush to show crescent moons or other forms [4.27]. The clouds are remarkable as an example of Turner's frequent practice of laying rich colour on wet ground, and leaving it to graduate itself as it dried, as in 'Venice from Fusina' (Fig. 4.13) [4.28].

The white of the paper or a white background has been used within paintings to highlight part of the imagery. In Figure 4.4, the dramatic effect of the wind-swept tree is increased by its being silhouetted against bare white on the paper [4.29] and the moon is shown by leaving the paper uncovered [4.30] in Figure 4.9. The drama of a scene is also expressed in Turner's frenzied handling; the greenish-browns have been worked with his fingers, as in Figure 4.4 [4.31]. In Figure 4.16, the form of the campanile is created by drawing a wide, wet brush through the pigment, so it looms excitingly against the sky [4.32].



Fig. 4.17 'Storm on Margate Sands', c.1835-40



Fig. 4.18 'Dawn after the wreck', c.1841

Turner's painting of familiar scenes, the fruit of observation and experience rather than imagination, has often led him to be viewed as a forerunner of Impressionism [4.33]. Monet and Pissarro saw the wonderful effects he achieved with a host of multicoloured strokes, dabbed in one against the other, and producing the desired effect when seen from a distance [4.34]. What Turner pioneered in watercolour in Figures 4.17 and 4.18, the Impressionists would later begin to achieve through the use of thick oil paint [4.35].

Turner's consideration of light, clouds, water and sand strip the landscape convention down to its essential aspects and anticipate not only the work of the Impressionists, but also of much later artists such as Rothko, for whom paint and canvas, the basic elements of painting, became subject matter worthy of investigation in their own right [4.36].

4.3.2 *French Impressionists*

As a stylistic theory, Impressionism was first applied to the work of nineteenth century painters such as Degas, Monet and Renoir. These artists were particularly interested in the visual effects of objects and light in a painting rather than in the realistic representation of a scene [4.37]. Camille Pissarro wrote to a student, “Do not proceed according to rules and principles but paint what you observe and feel.” [4.38].

The Impressionists profited from the discovery that juxtaposed complementary colours, when used in large enough areas, intensify each other [4.39]. Red and green, purple and yellow, blue and orange, sitting directly opposite each other on the colour wheel (Fig. 4.2), make each other appear more vivid when used side by side [4.40]. The Impressionists were also influenced by French chemist, Eugène Chevreul, and his discoveries regarding optical mixture - that two different colours fuse to a single more neutral colour when seen together from a distance [4.41].

As open-air painters, the Impressionists had become convinced that the colour of shadows was influenced by their surroundings – that they were not black, but rich in colour [4.42]. Chevreul’s theory eventually led them to tinge shadows with colours complementary to the colour of the object casting the shadow [4.43], i.e., the colour of a shadow will always be complementary to the colour of the light. For example, absolute white gives black shadow, red light gives green shadow, yellow light gives purple shadow, orange light gives blue shadow [4.44].

According to Pool, Monet’s ‘series’ pictures are the very essence of Impressionism. In 1891, he exhibited fifteen of his haystack series which show the same subject in a succession of different lights (Figs. 4.19 and 4.20) [4.45]. Dutch painter, Johann-Barthold Jongkind, discovered that ‘local colour’ changes with the season, painting two pictures of Notre-Dame from the same position but in different conditions: one in the cold morning light, the other during a warm sunset. It is likely that Monet, who derived so much from Jongkind, adopted this idea also [4.46]. The colours in Figure 4.19 give the image a more serene, quieter and calmer appearance, like a still winter’s morning, whilst Figure 4.20 appears more vibrant and energetic, literally more ‘colourful’. An interesting parallel to Jongkind’s findings is that photochromic dyes are affected by the atmosphere, with the depth of shade of the developed colours dependent on atmospheric conditions.



Fig. 4.19 'Haystacks: Snow Effect', 1891



Fig. 4.20 'Haystacks: Snow Effect', 1891

Renoir and Monet, in order to seize and convey a sensation of movement and quivering light, learned to handle paint more freely and loosely and did not try to hide their fragmented brush-strokes [4.47]. Alfred Sisley wrote about the diversity and quality of the Impressionist's brush work stating that he favoured using a different manner in different parts of the same picture; the sparkling water is represented by little fragmented touches of vibrant colour, whereas the fields and sky are more smoothly and softly rendered [4.48]. Cézanne eventually abandoned his big, curling brush-strokes in favour of smaller, more restrained daubs of paint which were sometimes applied with special knives enabling him to cover the canvas with dense layers of superimposed paint. He also achieved a great subtlety of surface and colours which were mosaic-like, as his palette became more luminous and his colours more vibrant and various [4.49].

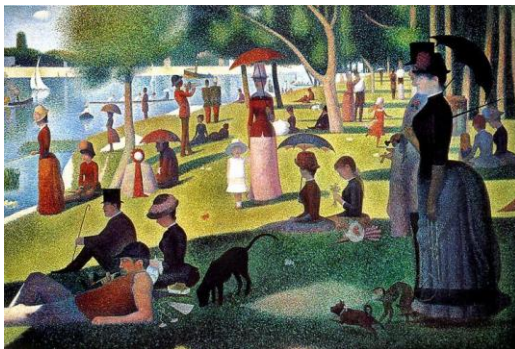


Fig. 4.21 'Un dimanche après-midi à l'Île de la Grande Jatte', 1884



Fig. 4.22 Detail of 'La Grande Jatte'

The technique of pointillism, used by Seurat, among others, and a progression from the Impressionist style, is essentially based on a technique in which the whole picture is composed of small dabs of paint, so-called 'taches', in different - but predominantly brilliant - colours [4.50]. The well-known painting by Georges Seurat, 'Un dimanche après-midi à l'Île de la Grande Jatte', illustrates this technique (Fig. 4.21). At a short distance, the dots and their colours are individually identifiable (Fig. 4.22).

Although Turner may have been called a precursor of the Impressionists there are, according to Zollinger, important differences between Turner and the true Impressionists. Whereas sharp colour and tone contrasts are found only occasionally in Turner's works, as can be seen in Figures 4.3-4.18, practically all Impressionist painting makes use of polar contrasts of chromatic colours, mainly complementary colours.

Although Turner and the Impressionists were mainly outdoor painters, Turner often depicted atmospheres tending to concentrate on the far distance whereas the Impressionists gave most of their attention to objects in the immediate foreground [4.51].

A visit to the National Gallery of Scotland enabled close-up observation of the Impressionist's work and the pointillist technique. The four paintings on display and viewed were Claude Monet's 'Poplars on the Epte' (Fig. 4.23) and 'Haystacks: Snow Effect' (Fig. 4.19), and Georges Seurat's 'A Study for 'Une Baignade' (Fig. 4.24) and 'La Luzerne, Saint-Denis' (Fig. 4.25).



Fig. 4.23 'Poplars on the Epte', 1891



Fig. 4.24 A Study for 'Une Baignade' 1883



Fig. 4.25 'La Luzerne, Saint-Denis' c.1885

My observations of the paintings have been summarised as below, and will be referred to when doing practical design development:

Brushstrokes: These varied in size from small to larger daubs. Some were neat, precise and petite strokes, and could be seen clearly going in all different directions. Some strokes were flat whilst others were uglier, thicker or swirling strokes.

Texture: The texture of the oil paint could be easily seen.

Canvas: The amount of canvas visible varied. At times the substrate could not be seen whilst at other times the cross-hatching texture of the underlying canvas was visible.

Colour: There were daubs of different colours, mainly sitting on top of one another. When viewed closely, there were lots of daubs of different colours. When standing further back, they blended in depth and shade.

Whereas the daubs of the Impressionists and the dots of the pointillist technique created the sensation of shimmering light or water with static daubs of paint, the movement of coloured dots and daubs, when controlled by artificial light, may be able to create interesting effects.

4.3.3 *Mark Rothko*

Diane Waldman's analysis of Rothko's paintings in her book, *Mark Rothko*, has been used as the main source of information about this artist, as she explores the aspects of his work that I am focussing on for this project.

According to Waldman, Rothko's goal was to make colour both area and volume, emotion and mood, at once palpable and disembodied, sensuous yet spiritual as colour represents something larger than its own sheer physical presence. Rothko came to think of colour as the doorway to another reality [4.52].

The artist experimented with his paintings in a number of ways: the size of the field and the interior configuration differed in relationship to one another and from painting to painting, the widths of the spaces between colours varied, colours ranged from bright to dark, from gay to sober, but were rarely sombre, with small amounts of black being introduced [4.53]. Dots, dashes, dragged lines and indeterminate contours, were all used to activate the surfaces of what were known as multiforms. Slowly Rothko more and more severely restricted their compositions and reduced the shapes in them, moving from pictorial to Surrealist forms, finally replacing imagery, and distilling the meaning of his earlier work, with colour. Though Rothko limited his forms and restricted his number of colours, his intention was to enhance rather than reduce the expressive possibilities of



Fig. 4.26 'Entrance to Subway [Subway Scene]', 1938



Fig. 4.27 'Multiform', 1948



Fig. 4.28 'Number 19', 1949

his paintings. To suggest multiple levels of meaning he had first to strip away extraneous detail. Figures 4.26-4.30 show the progression of Rothko's work from multiforms to a few rectangular shapes of colour.



Fig. 4.29 'Violet, Black, Orange, Yellow on White and Red', 1949



Fig. 4.30 'Number 22', 1949

Rothko's colour was full of contradictions and he frequently remarked he did not wish colour to be accepted at face value, asserting that dark paintings could be more cheerful than light ones, bright colour more serious than deep hues [4.54]. As he restricted his paintings to the simplest shapes and purified it even of colours, Rothko eventually limited himself to red, which was often the principal carrier of his emotions and ideas, and later accompanied this with black, which symbolised his state of mind and the character of his existence in the latter part of his life. Finally black was the only colour he used [4.55].

Spatial illusionism always played a part in Rothko's work. In virtually all his work from the time of the subway paintings, Rothko modifies it by dividing his canvas into horizontal bands which emphasise the canvas surface and therefore flatten the composition. But the paintings are not resolutely flat: his forms float ever so slightly above the colour field upon which they are placed. This depth is restricted, not only by means of frontality, but through feathery paint application which renders the rectangles almost transparent: the ground is revealed through the colour forms and appears to merge with them. In addition, Rothko often uses a band or accent of strong colour to reassert the picture plane. Despite the emphasis on the picture plane and the sense of shallow depth, there is in these paintings a curious, paradoxical fluctuation in space – the colour forms seem not only to hover on the canvas surface but actually to move forward. Because these veils of colour are so weightless, because there is about them a sensation of mist and atmosphere, they advance and appear to exist somewhere between

us and the picture, somewhere between what we know to be true and what we perceive [4.56].

For example, in 'Violet, Black, Orange, Yellow on White and Red' (Fig. 4.29), Rothko reveals his ability to hold on a single plane colours that advance and retreat. He achieves this through relatively simple means. The large violet shape in the uppermost portion of the canvas is far heavier than the smaller bands of orange and yellow below it. Rothko prevented this rectangle from toppling because of its weight by anchoring it with the thin band of black directly below it and with two vertical red bars which, despite their narrowness, effectively counter the strength of the violet mass. Furthermore, the soft yellow and white ground lent added density to the lower half of the painting and reinforced an otherwise recessive area [4.57]. The impact of this painting can be compared with his earlier work, 'Entrance to Subway [Subway Scene]' (Fig. 4.26), which is also split horizontally in bands of colour, with the pale pink walls against the darker floor. One tends to read the image from top to bottom on the flat canvas surface. Depth can be seen in the background, with the people in the distance, and foreground with the couple descending the stairs. Although both paintings are similar in this way, with or without motif, Figure 4.29 seems more successful from an emotional perspective. The simplicity and power of the colours seems stronger in this painting after Rothko had removed the 'extraneous detail' [4.58].

Rothko's preference for horizontal divisions within vertical canvases and configurations was replaced by an insistence upon horizontal divisions of horizontal supports. Where the vertical called to mind architecture, the horizontal alludes to landscape [4.59]. Additionally, although his compositions were generally weighted towards their tops (Figs. 4.29 and 4.31), Rothko occasionally concentrated his darkest, heaviest colours at the bottom of the canvas (Fig. 4.33) [4.60].

Much of this painter's art is identified by stacks of coloured, soft-edged rectangles that float on the canvas [4.61], as can be seen in 'Green, White, Yellow on Yellow' and 'Brown, Blue, Brown on Blue'. Analysing these, Waldman explains Rothko's technique and use of layering, placement, strength of colour and colour combination. In 'Green, White, Yellow on Yellow' (Fig. 4.31), fleeting glimpses of pink under-painting punctuate the large green upper mass, which is partially surrounded by a narrow border

of softly brushed white. There is a layer of green under-painting in the yellow block at the bottom of the canvas: it shines through the yellow, emphasising the sense of suffused light and also balances the composition. The yellow field behind the two rectangles provides yet another border of light and further unifies the painting [4.62].



Fig. 4.31 'Green, White, Yellow on Yellow', 1951



Fig. 4.32 'Brown, Blue, Brown on Blue', 1953



Fig. 4.33 'Homage to Matisse', 1954

Similarly, 'Brown, Blue, Brown on Blue' (Fig. 4.32), roughly square in shape, is illuminated by an electric blue in its midsection. So powerful is this blue that it must be offset by two darker and larger brown forms to prevent it from destroying the stability and balance Rothko seeks. Because the blue is more intense in value than the other colours, it would burst out of the rectangle if the heavier and denser masses of brown above and below it did not press in upon it to hold it in place. The blue field which surrounds the three bands (and is also behind them) locks them together in a single plane. Contradictions between foreground and background, flatness and shallow depth emerge and coexist in tenuous and ever-shifting relationships [4.63].

The ultimate effect of 'Homage to Matisse' (Fig. 4.33) is completely unlike that of 'Brown, Blue, Brown on Blue'. This difference is in part produced by Rothko's use of a long, narrow canvas. Once again he employs blue, here in the form of a rectangle at the bottom of the composition. It is surmounted by a floating, vaporous yellow square. The misty yellow and the red beneath it behave in an unexpected way. The red that peers through from underneath the yellow overlay has a bluish tinge ... Rothko must have made the square an extremely bluish-red [4.64].

As Waldman has explained, Rothko was able to create planes of colour that hovered and receded, balancing against one another. Using artificial light sources, the ability of the

colours of photochromic dyes to hover and be held in balance, when mixed or as a single colour, may be able to achieve a similar effect to Rothko's paintings.

Rothko perfected a technique of dyeing (or staining, as it later came to be called) with his paint that enabled him to saturate the threads of his canvas with his medium so that pigment and canvas become one. Paint was handled in a loose brushy manner, feathered out so that the edges of forms were never clearly defined. Variations in the thickness of paint produced nuances of colour. By applying many thin washes of paint, one over another, and often allowing some of the colours in the bottom layers to appear through the top coat of pigment, Rothko achieved the effect of a hidden light source. This effect was often enhanced by floating a thin seam or sliver of another colour through his rectangles or around their edges. The borders were also of extreme importance to Rothko, who constantly readjusted their proportions in relation to the inner configurations [4.65].

Despite the large size of his paintings, Rothko's work was refined and subtle and thus remains, despite its majestic proportions, intimate and emotionally accessible. As Rothko said: "I paint very large pictures ... the reason I paint them is precisely because I want to be very intimate and human." [4.66]. Rothko was said to have 'scaled his pictures so that the viewer is enveloped in their luminous, atmospheric surface.' The vertically stacked blocks of colour visually relate to the use of horizon lines, and his choice of colours is earthy and organic. The colours themselves are uneven which add a textural quality to the painting and forces the viewer to look into the painting [4.67]. Waldman describes the effect Rothko's art has on the observer, 'His colour, despite its intensity, becomes disembodied and seems to hover somewhere in front of the paintings ... the canvases are larger than life-size ... the spectator is encompassed by these floating colour shapes, drawn into space that exists somewhere between himself and the picture plane and is engulfed in an overwhelming emotional experience' [4.68]. A special, intensely personal relationship is achieved between the viewer and the canvas and, by extension, Rothko. Acutely aware of the need for this relationship, the artist noted: "A picture lives by companionship, expanding and quickening in the eyes of the sensitive observer. It dies by the same token. It is therefore a risky act to send it out into the world." [4.69].

4.3.4 *Howard Hodgkin*

Andrew Graham-Dixon's book, *Howard Hodgkin*, has been the main source of reference for information on the interpretations of Hodgkin's paintings for this project as it analyses and discusses the very relevant aspects of the artist's work that I want to access.

According to Graham-Dixon, Hodgkin is in many ways a very traditional painter, with his art asking old questions such as how do we apprehend the world? And how can the ways in which we apprehend it be communicated by a flat, painted image? [4.70]

Hodgkin himself has frequently emphasised that his work is filled with emotion. "The only way an artist can communicate with the world at large," he told artist and writer Timothy Hyman in 1978, "is on the level of feeling. I think the function of the artist is to practise his art to such a level that like the soul leaving the body, it comes out into the world and affects other people." [4.71].

Hodgkin's paintings exist at the margin between representation and abstraction, bright mosaics shot through with hints and suggestions and glimmerings of recognisable form [4.72]. References to the visible world may or may not be present in a specific picture, but that does not make such a picture any more or less faithful to its subject [4.73]. An example of this is 'Sunset' (Fig. 4.34). About death, it is one of the saddest and most moving of all Hodgkin's paintings and is described as follows, 'the dim shining of the sun, late in the day, is reincarnated in an image of colour - a threatened curve of modulated orange, blue, red, crimson - blotted out, blocked out, obscured by two great arcs of black and grey. Those great semicircular swipes of paint are like rainbows from which the colour has been drained, and the subject of the painting is at once the inevitable nightly draining of colour from the world and the thoughts it inevitably provokes' [4.74].

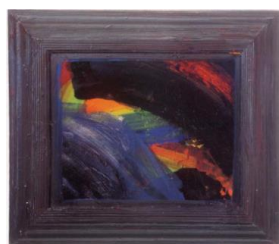


Fig. 4.34 'Sunset', 1990-93



Fig. 4.35 'David's Pool', 1979-85

Graham-Dixon comments, “The paintings are shot through with a sense of the transience of things ... In this art time passes visibly but not momentarily. No pattern, no cosmic order of events is suggested. The time of the pictures is, it might be said, the time of nineteenth-century painting - the time of the moment, the fleeting instant – accelerated to a point where imagery itself, the perceptible object, has been all but obliterated. ... No art, it was once thought, could ever be more of the moment than Impressionism, a creed as much as a school of painting, whose primary article of faith was truth to the perception of a single instant, the unrepeatable perception of light and shade, the wind fluttering the leaves on a tree in just *this* particular way, which it was the painter’s job to replicate on canvas. But the Impressionist canvas was, in truth, an extremely artificial recreation of that momentary experience: the moment itself was of such short duration, compared to the time necessary to complete the painting, that the painter was always in the position of reinventing the ‘truth’, in all the instantaneous freshness of its apprehension, long after its passage into the vault of the past.” [4.75].

A reference to any colour preference Hodgkin may have in his work states, ‘Red might be said to predominate - just - over blue, with green and yellow as incidentals and not much violet.’ [4.76].

Hodgkin’s characteristic repertoire of marks - stippled dots marshalled into loose grids, splotches, enlarged commas and fatly modelled cylinders - has come more and more to be dominated by long, broad brush-strokes [4.77]. “The language I use when I’m painting I have tried to keep to the most minimal, the most impersonal sort of marks that I can ... so the shapes that I use, as far as possible, are the shapes that are made by the mark of the brush.” [4.78]. “At one time I thought I’d become a completely pointillist painter: a dot or a stripe is something over which one has infinitely more control than something which depends on the movement of the arm ... To be an artist now, you have to make your own language, and for me that has taken a very long time.” [4.79].

Hodgkin also knows that a painting’s edge is its most vulnerable point. It is where the work of art ends and the world begins. It is where the painting, which - unlike the book, the play, the musical composition - has no given linear structure, no predetermined beginning or end, negotiates with its own limits. The edge of the painting is where the

artist makes his entrances and exits [4.80]. In 'David's Pool' (Fig. 4.35), trees and passing clouds cast their shadows in the water of the pool, with flagstones forming the border of the painting [4.81]. "The frames on my pictures are there fundamentally ... to protect the edges of the painting. But in my case the frames have become part of the pictures themselves in one way or another. Imagine having a very delicate emotion to convey something very slight, but perhaps very precious, one's instinct is to protect it more so it has a thicker frame, a bigger (sic) and so on and so on." Hodgkin also comments on the scale of his paintings. "How did I work out the size? Small pictures have an identity which can be incredibly intense. Large pictures have a different much more architectural physical presence and they have a completely different relation to the spectator. In a very big painting it is extremely hard to control where the spectator is going to stand." [4.82]. Describing how he judges whether a painting is finished, Hodgkin states, "... the picture is somewhere hovering in mid-air between myself and the spectator so that it looks as strange or as interesting or whatever to me as it does to any other spectator." [4.83].

Hodgkin states, "For me colour expresses feeling, it is also how I make pictorial architecture, it's also how I make things come forward and go back and even move around." [4.84]. Graham-Dixon describes Hodgkin's representations of Venice. 'This Venice is an unstable, watery place, where things come to view briefly, only to be lost again from sight; where things seem ghostly, barely apprehended; where they take on the fugitive quality of moving reflections seen in unstill water, or the quality of shadows. 'Venice/ Shadows' (Fig. 4.36) is a painting of opaque, shadowy mystery, an enigmatic red haze in which you see, floating (it could be a building or the shadow of a building), a single lozenge of green translucent paint. Hodgkin, so much of whose art is constructed around the tension between what is solid and what is fugitive, reinvents Venice as an image of his own preoccupations.'



Fig. 4.36 'Venice/ Shadows', 1984-88



Fig. 4.37 'Venice Grey Water', 1988-89



Fig. 4.38 'Love Letter', 1984-88

‘Venice Grey Water’ (Fig. 4.37) is described as the most watery and the most distilled of all the paintings. It is a small, liquid image of something that is always changing, from blue to green to grey to dark blue, an image that works its effects through layering and different levels of transparency and opacity [4.85]. Of ‘Love Letter’ (Fig. 4.38) Graham-Dixon states, ‘It feels like looking *in on something*.’ [4.86]. But the sense of looking through and into and beyond, so powerful in Hodgkin’s painting, also carries another charge. The painted world-within-a-world and the eye’s journey through to it become analogous for the painter’s own temporal struggle: the viewer’s struggle to get from one place to another, to make the leap from the world in front of the painting to the world within it, is a metaphor for the artist’s struggle to get from one time to another [4.87].

In 1890, Maurice Denis counselled painters to, ‘Remember that a picture – before it is a battle horse, a nude woman, or an anecdote – is in essence a plane surface covered with colours put together in a certain order’. This is illustrated in ‘In the Bay of Naples’ (Fig. 4.39), a tremendously sensual painting, almost a bravura demonstration of the things that the painter can make paint do: dots and blobs of red and blue and green paint bob and twinkle on a dark ground, like lights seen out at sea; a vertical bar of pink and blue paint evokes something quite different, more architectural, more solid; a liquid serpentine swathe of turquoise and dark blue and green paint at the painting’s centre, summarily applied in a few strokes of the brush, in a wave transmuted, boldly, simply, into one of Hodgkin’s many pictorial signs for water. This is not so much a landscape painting as a landscape of paint, a world of pleasure to be entered into. A painting can be, not just the world transfigured, but another world altogether. An instant elsewhere. The frequent references to travel in Hodgkin’s art ... say that to look at a picture should itself be to travel, to be transported, to be taken somewhere else [4.88].



Fig. 4.39 'In the Bay of Naples', 1980-82



Fig. 4.40 'Jealousy', 1977

‘Jealousy’ is described as a poisonous little painting of a poisonous little emotion (Fig. 4.40). Analyse the painting into its constituent parts, and you are left with nothing much in particular: a red blob silhouetted against a screen of green dots on a yellow ground, triply framed within bands of orange, dark brown and orange again. Analyse the painting into its constituent parts and you are left with an abstraction. But enter *into* the painting, and it becomes something different. That blob becomes a human figure, huddled and closed in on itself, locked away in some private room of some private house [4.89].

‘Passion’ presents a field of unevenly hued red interrupted by patches of swiftly applied paint the colour of blood and framed by a quasi-decorative border or wonkily pointillist dabs (Fig. 4.41). Its true subjects are clouding over and uncontrol (sic) and anarchy. It is an image of emotional disorder, phrased as the disordering of a pictorial scheme. A field of glowing colour, framed, is spoiled and invaded and messed up. Nearly all of the action of the painting is situated at its lower edge, where the dark, scribbled obliterations that intermittently cover the rest of the picture take it over and spill out. The picture is about what cannot be defined or contained or refined ‘Passion’ is about passion, and in this picture feeling is displaced from the figure to paint itself. It is paint itself - bloody, spilling, obliterating - that has been given the capacity to disturb and to evoke the disturbances of feeling [4.90].



Fig. 4.41 'Passion', 1980-84



Fig. 4.42 'Large Flower', 1986 [4.91]

As Graham-Dixon has shown, Howard Hodgkin has played with the abstract in combination with colour, to successfully enable the power of certain emotions to be conveyed. By capturing a sense of depth and movement using translucency and layering of static paints, he has been able to draw the viewer into the world of his paintings. By combining his use of colours, brushstrokes, scale and perspective he has you looking in on that feeling. Frequent references have also been made of his ability to use abstraction to create a transience of time and place. The colours of photochromic

dyes and their very transient nature will be explored in abstract designs to find their ability to express emotion and create the dimensions that Hodgkin has been able to achieve in, for example, 'Venice/Shadows (Fig. 4.36) and 'Love Letter' (Fig. 4.38).

In 1986 Hodgkin designed a print entitled 'Large Flower' for Designers Guild, which was, according to Tricia Guild, slightly ahead of his time (Fig. 4.42). "Contemporary art didn't hold the same values then as it does now, and it was before people got used to using contemporary fabrics. But as an artist, Howard is very flexible and forward looking. ... In this fabric, I see the artist, the painter. He didn't compromise the mark for the fabric. I find the marks very pure – they're extremely sensitive and strong at the same time ... it was a brave mark to make, and not many people understood that ride from work of art to textile ... Howard is a very strong person and open, so it didn't make him insecure to do something like that. I do think, though, that if he felt it wasn't going to be beautiful, he wouldn't have done it." [4.92]. The centre petal of each flower appears raised and flat with the petals on each side receding. Although Hodgkin's design is printed on a fabric substrate, there are definite edges, almost as though it is a three-dimensional structure made of paper or cardboard. As Tricia Guild has stated, it is very painterly. Painter's techniques will be used to create imagery on a fabric substrate for this project. It will be interesting to see how brush marks translate onto the fabric surface and whether a sense of depth can be captured.

4.4 Textile Artists

As this research is about the use of the colour of dyes on a textile substrate, feedback from textile artists about their use of colour to express their emotions within their own work was very informative.

4.4.1 Norma Starszakowna

The work of textile artist Norma Starszakowna combines photography, printing, embossing, collage, crushing and varnishing [4.93] to adorn and enrich the surface of textile substrates. Her use of colour effectively conveys to, or elicits from, the observer feelings or a sense of mood. This was evident on field visits to The Scottish Gallery and the Scottish Parliament to observe Starszakowna's work. As stated by Christina Jansen, director of The Scottish Gallery, "seeing and feeling the work is very important,

the shadows created are part of the effect, the technical process so complex as well as the way the piece makes you feel. It is very personal work.” [4.94].



Fig. 4.43 'Blue Sachem Wall' Fig. 4.44 'Yellow Stripe' Fig. 4.45 'Voices in the Mother Tongue'

'Blue Sachem Wall' (Fig. 4.43), a hanging textile, consisted of layers of shades of bright blues. It projected shadows, which resembled black, white and grey imagery that looked like grasses and rocks beside a stream, onto the wall behind it. The combination of the textile and its shadows evoked, in me, feelings of gentleness and intrigue. The rectangular sections of 'Yellow Stripe' (Fig. 4.44) consisted of many layered shades of yellows, oranges, light green, white, light browns and a light grey/brown colour. It appeared a very joyful piece, making me think of sand, the beach, grasses, debris, sunny whimsical holiday days and evoked feelings that could be described using the words harmony, peace, restfulness and tranquility. When it was hanging, the substrate appeared transparent causing the colours to change, with the green shade becoming more prominent. As a piece, it was noticeably more ordered than 'Blue Sachem Wall' and 'Voices in the Mother Tongue' (Fig. 4.45).

'Voices in the Mother Tongue' was initially observed as it lay on the floor. It was also made up of layering and used the colours black, orange, cream and pink. Words, symbols and numbers decorated the substrate beside different marks and scratches and the imprint of a flower pattern. There was great contrast between the black and orange colours. The coloured sections were not as neatly defined as those in 'Yellow Stripe', which were separated into square or rectangular blocks. Although the overall mood was darker, with some bright colours on the surface, it was not angry or aggressive, but harsh, sad and somehow jarring, and more dramatic than 'Blue Sachem Wall' and 'Yellow Stripe'. Rather than brightening a space, it made a dramatic statement. There appeared to be some conflict, haphazard turmoil, conflicting thoughts, perhaps a

political statement emanating from within the piece. It was as though many voices and thoughts were trying to say things. Some of these were brighter and more optimistic above and behind the darkness. Within the chaos, things were peeking through, like slats, blinds, things behind half hidden, some optimism, some trauma. When the same piece was hanging, it became transparent and cast patterns on the wall behind creating a different drama. It ‘talked’ more, the layers stood out more, and it seemed rather noisy.

In the work that I observed, Starszakowna used colours in the more traditional sense with bright yellows and oranges giving a sense of joy, whilst blacks and browns emanated a more sinister and traumatic feeling. Interestingly, the hangings projected shadows onto the wall, creating another dimension, to give another very different image, as occurred with ‘Blue Sachem Wall’. Or, as with ‘Voices in the Mother Tongue’, the patterns on the wall became more vocal.

4.4.2 Jill Blackwood

Textile designer and artist Jill Blackwood combines different fabrics such as silk, leather and linen, effectively weaving with colour. Colours are chosen based on an emotional response. For example, ‘God Shouting’ (Fig. 4.46), reminiscent of a bursting sun or mandala, is a response to the Homeopathic Hospital in Glasgow. Blackwood works very intuitively, all of her work based on how she feels at the time. When she receives a commission, she works in a sketch book, playing with ideas and the design - she “gets a feeling”. ‘Sizzle’ (Fig. 4.47) is a very colourful piece showing her “self-expression”. Blackwood finds it very helpful to get more distance from a piece, noting how the colours work when close up and further away as colour reads differently from different distances, stating, “the eye picks up different colours as the distance changes



Fig. 4.46 ‘God Shouting’



Fig. 4.47 ‘Sizzle’

that”. Blackwood creates her own colours by dyeing the fabric, saying that surprising things happen, overlaying one colour over another. She sees colours working together

as they are lying in a bundle when pulled out of a dye pot. She takes them out into the garden to look at them in daylight. “It’s the only way to do things, be ourselves,” she said. Blackwood also said she keeps fabric scraps in boxes and the light through the window spilling on the fabric “sets her off” as there is “a play of three colours”. The colours also change when the fabric is cut, depending on the light. Blackwood also works in black and white, finding it cleansing to move from a colour palette. Her kimono, ‘Great Expectations’, was about beginnings, endings, beginnings - the beginning can be black, the ending can be white, the end can be the beginning of something else. Working in black and white gives her time to reflect on colour pieces. She says it is harder working with black as it is dealing with shape, texture, outline and form. She stated, “Colour is exciting. The viewer always gets an emotional response. Black and white I think is more demanding of the viewer.” [4.95]

4.4.3 *Festival of Quilts field trip*

Textile artists and quilters use colour in various ways in their work. As Bente Vold Klausen stated, “I try to find unusual colours to go together, but still have harmony ... The colour sets the mood of the work and the choice of colour is important to me. Many people ask me why I use such dark colours, but I myself do not find them that dark! And I am a very optimistic and happy person, not depressive at all ... I am looking for colours that glow and have passion and temperament and colours that are dramatic.” [4.96] An example of the artist’s use of dark colours is in ‘Eternal Voyage/The Endless Journey’ (Fig. 4.48).



Fig. 4.48 'Eternal Voyage/ The Endless Journey' Fig. 4.49 'Colours - Singing in the Sun' (detail)

The small fabric squares of colour used by quilter Inge Hueber are reminiscent of the dots used by the pointillists. “My quilts are a technical construction on one hand, and a combination of emotional colours on the other,” she states. “I invent what I feel - the rhythm of life, changing emotions into colours and cloth ... to communicate and connect is getting more important in my mind.” [4.97] Hueber said her choice of colour was

instinctive [4.98]. When asked about how she uses colour to express emotion in her work she stated, “In my mind it is a very direct respond (sic), in "my pursuit of happiness" I use colours which can do just this, I choose them intuitively and I could hear from visitors at the Festival that these choices of mine are understandable to others as well and in the same way.” [4.99]. 'Colours - Singing in the Sun' (Fig. 4.49) is an example of this. The colours used in her exhibition were sunny and cheerful and I noticed I left her stand feeling very happy.



Fig. 4.50 'High Tide/Low Tide'



Fig. 4.51 Close up of 'High Tide/Low Tide'

Hueber also described how shadow and light are utilised in her work, “I just decided to like the ‘wrong side’ better and turned the top over. Seams and threads add texture, they capture light and shadow.” [4.100]. By placing her small square pieces of fabric in a specific arrangement, Hueber adopted a technique similar to that used by the Impressionists. The squares combine to ebb and flow as waves of colour creating the effect that the quilter wanted to achieve (Figs. 4.50 and 4.51).

Dorothy Caldwell’s choice of colours was for another reason. “Because I use very graphic black and white fabric as a base for my work, the small concentrated amounts of colour are very important in giving the work emotional warmth and richness. Working in a region (Ontario, Canada) where the landscape is black and white for a great part of the winter and a bland earth colour during the Spring and Fall, the intense colour from a bright green wheat field, a patch of red dogwood, or the yellow larch are what keep the landscape lively during these seasons.” [4.101].

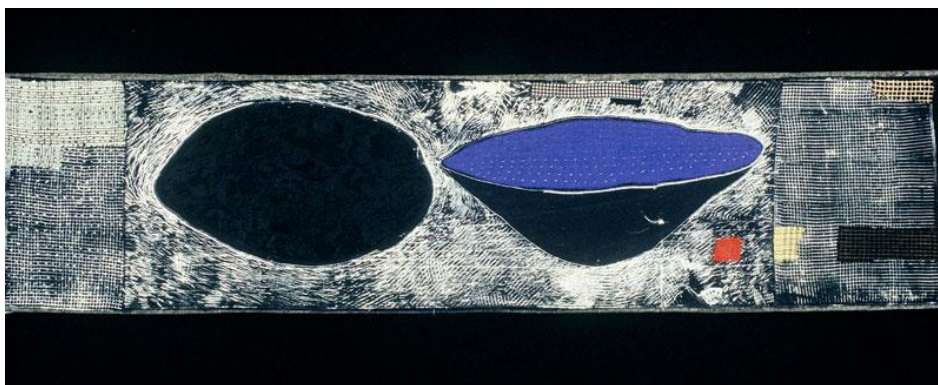


Fig. 4.52 'A Lake/A Bowl', 2002

Initially Caldwell studied as a painter and cites a Mark Rothko exhibition as having made a deep impression on her. She often longed for a strong textile tradition to work in and recognised this in quilting. The surface treatment used in Rothko's paintings, that stained so lightly that the weave of the canvas came through, provided the key to what has become her signature of deep, rich saturated colour from both dyeing and discharge. Her preference is to use discharge, working from dark to light to remove rather than add colour, and stitching that is so intense as to be an integral extension of the cloth on which she works. Although her stitching has been described as like scratches, scarring the surface with subtle shading and motion, it can also be likened to the painter's daub (Fig. 4.52). Her use of the grid, although for appliqué, appears mosaic-like on the fabric substrate (Fig. 4.53) [4.102].

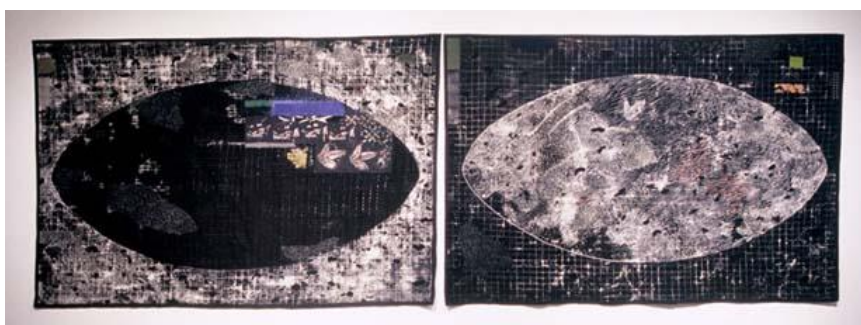


Fig. 4.53 'An Island/A Pond', 2002

Like Jill Blackwood, Pauline Burbidge sometimes chooses to work in black and white stating, "I often choose to work in black & white only, during some periods in my work (Figs. 4.54 and 4.55). For example, during this year 2008, I chose to make my whole 'Quiltline' collection (both functional quilts and 'Stitch Drawings') all in black and white.

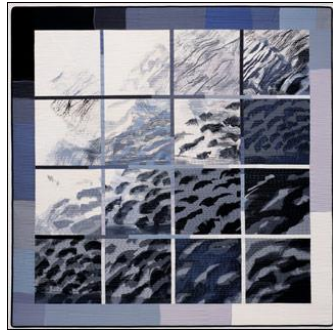


Fig. 4.54 'Wind over water'



Fig. 4.55 Detail of 'Wind over water'

It is a great way of paring things down, returning to basics, and focusing on the line and drawing, without the distractions of full colour. Throughout my career of making quilts I have often returned to using simply black & white - it gives me a feeling of wiping the slate clean, of starting afresh.” [4.103].

4.4.4 *Raymond Honeyman*

The textile designer Raymond Honeyman states, “Colour is unquestionably the most important aspect of designing textiles as our instinctive response to seeing colour stirs our emotions.” [4.104]. Building up his pictures with dots of paint, the designs of his needlepoint tapestries are mapped out on paper (Fig. 4.56).



Fig. 4.56 Close-up of paint daubs



Fig. 4.57 Painted artwork for 'Paper Fans'

When LEDs are used to develop the photochromic dyes, circular dots of the dye colour become visible. These dots may be used to build up images in a way similar to that of Honeyman’s artwork. Contrary to the Impressionist’s use of complementary colours, Honeyman uses different shades of the same colour to effectively illustrate depth and shadow (Fig. 4.57).

4.5 Summary

The research has shown that colour can be used in a diversity of combinations, proportion, placement, motif or abstraction to convey an emotional experience to the observer. For example, Hodgkin’s small paintings use a large range of colours in

abstract forms whilst Rothko progressively minimised his palette and forms until he used only a single colour covering the whole large canvas. Both painters use colour to create layering and depth in their work. Turner's paintings, more pictorial and representative than both Hodgkin's and Rothko's, show how the same colour can be used in different proportions and placement to convey opposite meanings. Different painting techniques were used by each of the artists as they applied the paint to the substrate, with their particular characteristic techniques enabling them to express the intangible in themselves and, although not a certain eventuality, access it in the viewer.

There were parallels between the work of the painters and the textile artists. Hodgkin uses dots and daubs (amongst larger strokes of paint) in his paintings, as did the Impressionists, whilst Raymond Honeyman uses dots of paint to map out his needlepoint designs. Inge Heuber uses coloured fabric squares to create her quilts and in some of her works mimics the Impressionist's technique. Like Rothko and Turner, Starszakowna uses bands of colour.

Like the painters, the textile artists are also guided by their feelings. As Blackwood states, she "gets a feeling" and her work shows her "self-expression ... it's the only way to do things, be ourselves" [4.105]. Heuber explains her approach to her work, "I invent what I feel – the rhythm of life, changing emotions into colours and cloth ... to communicate and connect," [4.106] and her choice of colour is instinctive [4.107] and intuitive [4.108].

Although Turner demonstrated the ability to use colours from anywhere on the spectrum to express opposing moods and, like Rothko, Bente Vold Klausen asserts that dark coloured paintings could be more cheerful than light coloured ones, there was a tendency for yellows, oranges, reds and pinks to express joyful, happy pieces whilst the more sombre moods were expressed with duller, deeper shades. Dorothy Caldwell uses colour to add emotional warmth to her otherwise very graphic black and white quilts, Blackwood uses black and white to contemplate her use of colour whilst Burbidge uses it to simplify her working method.

The substantial information gathered in this research will be used as a guide for the development of design work. However, the artists have shown that their work is a very

personal endeavour. It is something from inside the maker - how they feel and how they capture and express that feeling on the static canvas, either with paint or coloured fabric. In reference to their moving image, the French Impressionist filmmaker's stated, "Above all it should be an occasion for the artist to express feelings ... something not immediately or materially apparent must be brought out, evoked, led forth." [4.109] [4.110]. This therefore raises the question, "Can visual effects be created that convincingly draw from another an emotional response? How will I be able to determine if the colours of these dyes, that are able to appear and disappear from the textile substrate, have been successful in expressing what I, as the creator, feel inside? Are the dyes able to be used to express beauty [4.111] or will the image appear dull and lifeless, without the necessary degree of subtlety needed?" At its conclusion, this aspect of the project may be open to relatively subjective comments, whereas a critique of how the dyes work in a practical manner would be a more measureable judgement. Both of these aspects of the dyes will be explored.

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Chapter 5

Experimental Development

Experimental Development

5.1 Introduction

Photochromic dyes can be developed using the abundant and free source of natural UV light available from the sun. As the strength of the sun varies, depending on the season and the hemisphere, the colour response of the dyes varies. The dyes respond most favourably to strong UV light in cool atmospheric conditions when they develop optimally in colour. Heat adversely affects the dyes, helping drive the reaction back to the uncoloured form. Therefore, in very hot conditions there is always competition between light and heat to determine the given colour observed. Similarly, in cold conditions in the presence of sunlight, an intense colour is observed as there is little or no competition from the back reaction [5.1]. The latitude of a country, seasonal changes and the time of day affect the dyes' performance. Consequently, designs that are reliant on the sun have to take into consideration, and interact with, the prevailing environmental conditions and any subsequent changes that occur. As the UV light appears and disappears with the sun, it effectively determines the development of the dyes within the design. As we cannot command the sun, the manifesting design is determined by how much sunlight is available. This interdependent relationship between the design and the sun is not controllable although it is manageable, using certain combinations of factors to give a predetermined outcome. Being able to manage the dyes more precisely would require the use of another source of UV light, an artificial one. Then, perhaps, the colours of the dyes could be directed to give a decided effect that had less reliance on, and input from, other elements.

There was very little documented information available about photochromic dyes that could be used when applying them to the fabric substrate or for their use within textile design. From a practical perspective, familiarity with using the dyes and an understanding of their working capabilities was needed. Therefore, they were explored in a range of testing scenarios to gain a grasp of how they work so as to provide a baseline for the project.

This chapter sets out how a selection of photochromic dyes of various colours were printed on a range of substrates and in a variety of simple designs to answer questions related to colour appearance, movement and interaction, mixing, proportion and placement, and development and fading, among others. The effect of the substrate on dye performance was observed. The dyes were extruded in polypropylene to make a

monofilament and the responses of the dyes to various sources of artificial UV light observed. The fade rates and fading behaviour of both printed and extruded dyes when developed by LEDs was also examined. As the dyes are expensive consideration was given to the testing carried out.

5.2 Standard Printing Procedure for Photochromic Dyes







A printing mixture and procedure was developed by Galbraith [5.2] for applying photochromic dyes to a textile substrate. This was altered by Little [5.3] for 100g of print paste, so that optimal dye colour could be obtained with minimal base colour visible on the printed fabric background. The base colour in a system is due in part to the shade of the dye in powder form which can be quite coloured. It may be minimised by reducing the dye concentration or by the addition of permanent dyes [5.4]. Using this printing procedure, a range of the dyes were mixed, printed and finished as set out below.

5.2.1 *Dyes that dissolve without heating*

For 100g of print paste:

- 0.05g Reversacol dye ('Aqua Green', 'Corn Yellow', 'Flame', 'Midnight Grey', 'Palatinate Purple' and 'Rush Yellow') in dry powder form
- 10ml acetone
- 100g Bricoprint binder SF20E

1. 0.05g Reversacol dye powder was dissolved in 10ml acetone in a small labelled beaker in a fume cupboard. The solution was stirred manually with a glass rod until all of the dye powder had dissolved. Once dissolved in the acetone the colour of the dye/acetone solution changed as follows:







- 'Aqua Green' became clear bright green 
- 'Corn Yellow' became clear bright yellow 
- 'Flame' became clear dark orange 
- 'Midnight Grey' became clear dark grey 
- 'Palatinate Purple' became slightly cloudy, very dark green 
- 'Rush Yellow' became clear 

2. The dye/acetone solution was then added to a larger labelled beaker containing 100g of pigment binder. This was stirred manually using a glass rod.

Mixing the pigment binder with the photochromic dye/acetone solution differs from mixing pigment binder with coloured pigment as, although coloured, the dye/acetone solution is not sufficiently visible as it combines with the binder. Taking the beaker with the print paste out into sunlight initially seemed to be a way of observing for any unmixed dye solution, as when it was exposed to sunlight the print paste developed into its photochromic colour. For example, very pale peach coloured 'Flame' print paste turned orange. It seemed that stirring the paste in sunlight combined the unmixed parts of the mixture together. However, the process of stirring brings previously unexposed parts of the mixture to the surface, exposing them to sunlight and the photochromic colour develops. As parts of the mixture are stirred back into the beaker they are removed from the sunlight and fade back to colourless or a very pale colour. As the stirring continues the undeveloped parts of the mixture reach the surface and begin their photochromic response to sunlight, and so it continues.

As the quantities of pigment binder used for each dye are small, using an electric mixer was inappropriate. Therefore, the mixture required very deliberate and thorough stirring by hand to ensure sufficient blending.

Although photochromic dyes are invisible, or only lightly visible, until developed by UV light, the colour of the dye and pigment binder paste when combined in the beaker was as follows:

- 'Aqua Green' became very pale green 
- 'Corn Yellow' became very pale yellow 
- 'Flame' became very pale peach 
- 'Midnight Grey' became white 
- 'Palatinate Purple' became very pale green 
- 'Rush Yellow' became white 

3. Each beaker was covered with cling film.






5.2.2 Dyes that require heat to dissolve

For 100g of print paste:






- 0.05g Reversacol dye ('Cardinal', 'Claret', 'Oxford Blue', 'Sea Green' and 'Volcanic Grey') in dry powder form
- 10ml acetone
- 100g Bricoprint binder SF20E

1. 0.05g Reversacol dye powder was dissolved in 10ml acetone in a small labelled beaker in a fume cupboard. It was stirred with a glass rod.

2. The beaker was placed on a Corning Hot Plate Stirrer at heat 2. It was carefully observed so the dye/acetone solution did not simmer. The beaker was intermittently removed from the hot plate and stirred. All of these mixtures dissolved within five minutes. Once dissolved in the acetone the colour of the dye/acetone solution changed as follows:

- 'Cardinal' became clear red 
- 'Claret' became clear dark lilac 
- 'Oxford Blue' became clear deep blue 
- 'Sea Green' became clear dark green 
- 'Volcanic Grey' became clear dark purple/grey 

3. The procedures described in stages 2 and 3 of Section 5.2.1 were then followed. The colour of the dye and pigment binder paste in the beaker changed as follows:

- 'Cardinal' became very pale pink 
- 'Claret' became very pale lilac 
- 'Oxford Blue' became white 
- 'Sea Green' became very pale green 
- 'Volcanic Grey' became very light mauve/grey 

5.2.3 *Dyes that are not readily dissolved*

For 100g of print paste:

- 0.05g Reversacol dye ('Plum Red') in dry powder form
- 10ml acetone
- 100g Bricoprint binder SF20E


1. 0.05g Reversacol dye powder was dissolved in 10ml acetone in a small labelled beaker in a fume cupboard. It was stirred with a glass rod.

2. The beaker was placed on a Corning Hot Plate Stirrer at heat 2. ‘Plum Red’ did not dissolve as readily as the other dyes. Adding more acetone as it was heating enabled the dye to dissolve. Once dissolved in the acetone the colour of the dye/acetone solution changed as follows:

- ‘Plum Red’ became clear dark plum red 

3. The procedure described in stages 2 and 3 of Section 5.2.1 was then followed.

The colour of the dye and pigment binder paste in the beaker changed as follows:

- ‘Plum Red’ became very pale lilac 

Dye	Powder/ granules	After acetone added	After heated	Combined with pigment binder
‘Aqua Green’	yellow powder	clear bright green		very pale green
‘Cardinal’	pale apricot granules	clear red	clear red	very pale pink
‘Claret’	cream powder	clear dark lilac	clear dark lilac	very pale lilac
‘Corn Yellow’	dark cream powder	clear bright yellow		very pale yellow
‘Flame’	dirty pale apricot powder	clear dark orange		very pale peach
‘Midnight Grey’	pale yellow powder	clear dark grey		white
‘Oxford Blue’	very pale yellow powder	clear light blue	clear deep blue	white
‘Palatinate Purple’	yellow powder	slightly cloudy very dark green		very pale green
‘Plum Red’	yellow/apricot powder	clear lilac	clear dark plum red	very pale lilac
‘Rush Yellow’	white crystals	clear		white
‘Sea Green’	yellow powder	clear green	clear dark green	very pale green
‘Volcanic Grey’	pale grey ‘fluff’	clear mauve/grey	clear dark purple/grey	very light mauve/grey

Table 5.1 Colours of dyes as they are prepared for printing

Reversacol dyes are not active in their crystalline powder form but when combined with an appropriate solvent, ink or plastic will readily change colour upon exposure to ultraviolet light sources [5.5]. Table 5.1 shows the colours of photochromic dyes at various stages as they are prepared for printing (they have not been exposed to UV light). Although beakers were labelled, this information would be helpful for identifying the dyes at any stage of the preparation process.

5.2.4 Printing the fabric

A Johannes Zimmer Print table was used for all printing. The print table settings for the 1cm magnetised rod were placed at Pressure 3 and Speed 4 for all printing. A plain mesh printing screen was used.

1. The name of the dye to be printed on the fabric was marked in a corner of the reverse side of the fabric.
2. The fabric was placed on the print table. Masking tape was used to secure it into position.
3. The print screen was placed on the print table on top of the fabric. The stoppers on the print table were placed on either side of the print screen and tightened, securing the screen in place.
4. The magnetised rod was placed on the print screen behind the image to be printed ensuring the magnetic bar was lined up with the magnetised rod.
5. The print paste was placed on the screen, using a spatula, in front of the magnetised rod.
6. The dial on the print table was used to operate one pass of the magnetised rod across the surface of the print. The magnetised rod was turned off.
7. The screen and magnetised rod were lifted off the print table.
8. The printed fabric sample was carefully lifted off the print table onto a piece of A4 paper.
9. The print screen and magnetised rod were thoroughly washed with the power hose and left to dry.

5.2.5 Drying and baking the fabric

The Gallenkamp Hotbox oven was preheated with the temperature set at 100°C. The Roaches Laboratory Oven was preheated with the temperature set at 140°C dry heat. The oven timer was set at five minutes.

1. The A4 paper with the printed fabric was placed into the Hotbox oven to dry for 10 minutes.
2. The fabric was then placed on the tray of the Roaches Laboratory Oven with the edges of the fabric placed over the spikes that are on the side of the oven tray. The wheel brush was rolled over the edges of the fabric so that the spikes secured it in place. The fabric was baked for five minutes.

5.3 Testing Dyes on Substrates in Combination with Experimental Motifs

5.3.1 Photochromic dyes tested on six different substrates

The Reversacol dyes used for testing were:



The dots shown above give an indication of the colour of each dye when it has developed.

As the dyes respond differently on different substrates [5.6], they were printed on a variety of fabrics to observe the appearance of their colours. Natural fibres were chosen initially with the anticipation that their textural appearance would be one of warmth and comfort as they are placed in the home environment, more so than that given by synthetic fibre materials. See Appendix A.

Observations:

Standard print room screens were initially used for convenience as a starting point for printing with these dyes. The screens were chosen on the basis of a variety of criteria, i.e., thickness of line of the design, repetition and placement of pattern. Each dye was printed using each of the screens. A subjective assessment of the dyes printed on fabric was made based loosely on the following criteria in natural UV light, i.e., sunlight:

- actual hue
- intensity of colour
- print definition

In this project the following terms were used:

- ‘not developed’ or ‘undeveloped’ refers to the appearance of the dyes when printed on fabric before they have been exposed to UV light.
- ‘developing’ refers to the dyes as they move through the process of being ‘undeveloped’ to being ‘developed’.
- ‘developed’ refers to the dyes when they have reached the brightest colour that they will achieve when printed on the substrate.
- ‘fading’ refers to the reversal of the process, i.e., as the dyes revert from being ‘developed’ to being ‘undeveloped’.

All of the tests carried out on these dyes will be subjective, using naked eye perception, for two reasons. Firstly, from a design perspective, the consumer would see the colours and the movement of the dyes from their subjective standpoint. Secondly, as explained in Section 5.1, on different days in different weather the intensity of the resulting colours may vary. The intensity of the activated shade changes according to the UV light present in the atmosphere, however to what degree is not measurable visually. This would require specialised spectrophotometer testing [5.7]. Similarly, atmospheric conditions were not measured.

Results:

It became apparent that residual dye left on the screen from previous printing, using non-photochromic dyes, was staining the fabric substrate (Fig. 5.4). Therefore, screens need to be thoroughly cleaned to remove any residual dye before printing with photochromic dye.

The fabric was taken outside into sunlight to watch the dyes develop. This was a simple and effective way to see the results of printing. If observing the development of the dyes in sunlight is inconvenient, an artificial light source such as a handheld UV lamp could be used.

‘Aqua Green’:

‘Aqua Green’ appeared light green when developed as shown by the printed thick lines of Figure 5.1. The strength of colour, by comparison with the other photochromic dyes, was not very bright. The print definition was even and fine lines were clearly defined. Residual dye marred the colour of the developed photochromic dye. The texture of the substrate of the silk chiffon caused some haziness to the printed design. ‘Aqua Green’ was also printed on a piece of raw silk. The slubbiness of the fabric caused the definition of the design to be uneven.



Fig. 5.1 Developed ‘Aqua Green’ dye



Fig. 5.2 ‘Flame’ appears lighter on the silk chiffon at top of picture

‘Flame’:

The colour of ‘Flame’ appeared to be distinctly orange when developed. The actual shade could be described as burnt orange. The dye printed evenly across the substrates. However, on the silk chiffon, which was a light weight and loose weave fabric, ‘Flame’ was not as strong in colour as on the other fabrics (Fig. 5.2) and the definition of the print not as clear, with the texture of the substrate causing some haziness to the printed design. On the remainder of the fabrics the print definition was clear for all of the designs. The fine lines were well defined. The staining from the residual non-photochromic dye was variable on each of the substrates and did not visibly affect the resulting colour of the developed ‘Flame’ photochromic dye.



Fig. 5.3 Developed ‘Oxford Blue’ dye



Fig. 5.4 Undeveloped ‘Oxford Blue’ with red residual dye



Fig. 5.5 Developed ‘Oxford Blue’ with residual dye

‘Oxford Blue’:

‘Oxford Blue’ appeared pale blue when developed under natural UV light (Fig. 5.3). The print definition was even. The fine lines were well defined. The texture of the substrate of the silk chiffon caused some haziness to the printed design. Residual dye (Fig. 5.4) marred the colour of the developed photochromic dye, with the resulting colour being a muddy blue/purple (Fig. 5.5). This shows that the red residual dye and the blue photochromic dye mixed to make purple, as would usually occur with colour mixing of ordinary dyes or pigments.

‘Palatinate Purple’:

It was noted that when ‘Palatinate Purple’ was printed on the cotton/linen fabric, it appeared very pale green in colour before developing (Fig. 5.6). It was not visible on the other fabrics before development. When developed, the printed ‘Palatinate Purple’ appeared dark blue on all of the substrates (Fig. 5.7). The strength of the developed colour was consistent on all of the fabrics. The definition of the colour was even with all of the prints. The fine lines were well defined. When the ‘Palatinate Purple’ faded after development it returned to the very pale green colour. This dye was also printed

on a sample of raw silk. Again, the design printed on the raw silk was not adversely affected by the texture of the fabric.



Fig. 5.6 Undeveloped 'Palatinate Purple' appears pale green



Fig. 5.7 Developed 'Palatinate Purple' dye



Fig. 5.8 Developed 'Rush Yellow' dye
Darker yellow areas at top of picture from combination of non-photochromic dye and photochromic dye

'Rush Yellow':

When developed 'Rush Yellow' appeared bright yellow on all of the fabrics (Fig. 5.8). The print definition was even. The fine lines were well defined. In some areas of the designs, where residual non-photochromic dye had transferred to the printed fabric, the combination of the two dyes meant the resulting visible colour was stronger in some areas than in others, i.e., a darker yellow in some parts of the print, without the actual hue altering, as occurred in previous samples. This dye was also printed on a sample of raw silk. The texture of the fabric did not adversely affect the print definition.

The strength of colour of the dyes was compared on the crinkle cotton samples as they appeared to develop most strongly on this substrate. As shown in Table 5.2, 'Flame' and 'Palatinate Purple' were the brightest colours, followed by 'Rush Yellow'. 'Oxford Blue' and 'Aqua Green' were noticeably the palest.

Dye	Intensity of colour
'Oxford Blue'	1
'Aqua Green'	2
'Rush Yellow'	3
'Palatinate Purple'	4
'Flame'	5

Table 5.2 Intensity of colour of the dyes in natural UV light

Table key

1 = exhibits least of this property (in this case the palest)

5 = exhibits most of this property (in this case the brightest)

Discussion:

Ordinarily any residual dye from a print screen would not be noticed if it was transferred to fabric when printing using permanent dyes, as it would be very minimal in quantity and masked by the current dye being used. The acetone in the photochromic print paste may have dissolved the residual non-photochromic dye from the screens enabling it to then transfer to the fabric. As photochromic dyes are colourless or very pale before they have developed, any residual non-photochromic dye transferred from the print screen would be visible, and stain a light coloured substrate as the photochromic dyes were printed, as demonstrated. Industrial printing companies use new screen mesh for each new design to be printed, therefore this would not occur in that scenario. However, independent designers re-use screen mesh by removing the emulsion that has been used to coat each screen. After printing, some pigments and dyes (particularly those that are red) leave traces on the screen mesh. Therefore, a way of stripping the screens to remove all dye would need to be found if using a power hose was insufficient. Perhaps acetone or another solvent could be used to clean the screens to ensure removal of any residual dye prior to printing with photochromic dyes.

When the photochromic dyes developed the residual dye was not always very noticeable. This could be used purposefully when designing and printing. For example, a design could be printed using a pale colour of non-photochromic dye and overprinted with photochromic dye. When the photochromic dye developed, the initial print, or part thereof, would disappear from view as the photochromic print took its place. Additionally, as with 'Rush Yellow', the resulting developed colour may become a darker shade. Mixing photochromic dyes with permanent dyes in varying quantities, either together in the print paste or by overprinting, could be examined further in future research to fully positively utilise this occurrence.





'Palatinate Purple' was visible before exposure to UV light on the thicker fabric. This will need to be taken into consideration when choosing the substrate, however this change from pale green to dark blue may be used as part of a design. Additionally, the fibre composition and texture of the fabric substrates affected the strength of colour of the developed dyes.

It quickly became apparent that the dyes would need to be photographed to record their appearance when they developed on the fabric as memory is not sufficient for

comparison, reflection and development of ideas. Although the resulting colour of the images varied when the photographs were printed on paper (as printers, levels of ink, etc, varied), they were sufficient for reference. This necessity for photography considerably increased the time taken for all procedures when working with these dyes.

5.3.2 *Bird design*

The Reversacol dyes used for testing were:

‘Flame’  : ‘Oxford Blue’  : ‘Palatinate Purple’  : ‘Rush Yellow’ 

An existing design that incorporated a bird and various motifs was printed using several photochromic dyes (Fig. 5.9). The aim of using this design was to observe the appearance of the colours of the dyes when placed together in combination on a larger piece of fabric. The stated dyes were used as they are of contrasting colours. See Appendix B.1.

Observations:

The following observations were made of the printed design when it was exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- intensity of colour

Results and discussion of printing on silk:

‘Palatinate Purple’ appeared a very, very pale green on the substrate before developing. There was also a small section of staining from residual pink dye on the silk from when the screen had been used previously with non-photochromic dyes.



Fig. 5.9 Original *Bird design* on paper



Fig. 5.10 Undeveloped dye showing pigment binder



Fig. 5.11 Flooding of the ‘Rush Yellow’ dye

From certain angles the printed white binder in the print paste made the motifs visible prior to development (Fig. 5.10). There was a noticeable contrast between the shiny silk substrate and the matte pigment print. This would be due to the fineness of the fabric. Ordinarily the printed areas would be coloured (not initially invisible) and a dye more appropriate for use on the thin, fine and light weight silk would be used. As photochromic dyes use pigment binder as a means for applying them by printing to a substrate, this would need to be taken into consideration when choosing a substrate to use with these dyes. A thicker more appropriate substrate will need to be identified for use within this project.

Figure 5.11 shows the flooding of the 'Rush Yellow' dye in the top left and bottom right hand corners of the print (see original motif in Figure 5.9). This is because the quantity of acetone (required to dissolve the dye powder) made the print paste too thin for this light weight fabric. The use of thickener would solve this problem.

The motifs were all placed separately from one another within the design and printed in different colours. The cream background was left unprinted incorporating the colour of the fabric into the design. Although the developed colours appeared to be the same as those on the printed fabric samples in Section 5.3.1, their effect was pale against the cream background. The lines of the design were very fine. A combination of the cream spaces between the motifs and the choice and placement of the colours gave the design an indifferent appearance. The flooding of the dyes and the subsequent decrease in clarity of print definition contributed to the overall disappointing result.

Although it is not always necessary to use registration crosses, the printing of this design reinforced the necessity for their use when using photochromic dyes. When using permanent dyes the printed image is visible enabling any adjustment of the print screen to be made, i.e., to line it up with the motifs that have already been printed. When using photochromic dyes the printed motifs were not visible (or only lightly visible) and some overlap of the printed colours and misplacement of the screen occurred.

The Reversacol dyes used for testing were:

'Aqua'  : 'Flame'  : 'Palatinate' 
'Green'  : 'Purple' 

The same design was then printed on linen. ‘Aqua Green’, ‘Flame’ and ‘Palatinate Purple’ dyes were used as they provide contrasting colours. In this print a dye was used for the background colour. See Appendix B.2.

Observations:

The following observations were made of the printed design when it was exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- intensity of colour
- the appearance of the design when a background colour was printed

Results and discussion of printing on linen:

The dyes, including ‘Palatinate Purple’, were not visible before development however there was a small section of staining of pink residual dye on the linen from when the screen had been used previously with non-photochromic dyes. Again this highlighted the importance of screen cleanliness.

Although flooding also occurred on the linen it was not as marked as on the finer silk fabric. Again, using thickener, or alternatively, decreasing the amount of acetone used for dissolving the dye, may help to make the print paste a more appropriate consistency for printing on this or other fine fabrics.



Fig. 5.12 *Bird design on linen showing pale colours*

The developed colours were not noticeably brighter when printed on linen than on silk (Fig. 5.12). ‘Aqua Green’ as a background colour did not improve the appearance of the print. The contrast between the colours used in the silk print (Fig. 5.11) and its

white background gave the dyes a brighter appearance than when the ‘Aqua Green’ was used as a background colour. Replacing it with ‘Palatinate Purple’, a much brighter dye, may have given the design a more striking appearance. The way the dyes are used in placement within designs will need to be considered.

5.3.3 *Stripe design*

The Reversacol dyes used for testing were:

‘Aqua Green’  : ‘Flame’  : ‘Oxford Blue’  : ‘Palatinate Purple’ 

In the previous samples, although the dyes developed and faded, the interplay of the colours as they moved was not very apparent. This may have been because they were positioned separately from one another on the substrate and the background was white or very pale in colour. Therefore, a stripe design where the colours of the dyes were sitting side by side covering the whole substrate (Fig. 5.13) was printed. There was no white or cream in the design. It was comprised of colours similar to those of the photochromic dyes that were available for use. It also gave the opportunity to mix two dyes together to make a specific colour. The aim was to observe the appearance of the colours of the dyes as they sat closely together covering the whole substrate and to observe their fading pattern in this simple placement. See Appendix C.

Observations:

The following observations were made of the printed stripe design when it was exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- intensity of colour
- fading order

Results:

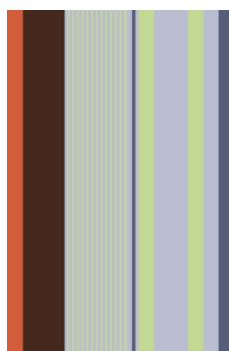


Fig. 5.13 *Stripe design* on paper



Fig. 5.14 Undeveloped dye in *Stripe design*



Fig. 5.15 Developed dye in *Stripe design*

Stripe design colours from left to right – ‘Flame’, ‘Brown’, ‘Oxford Blue’ and ‘Aqua Green’ alternating, ‘Palatinate Purple’, ‘Aqua Green’ and ‘Oxford Blue’ alternating, ‘Palatinate Purple’.

The dyes were not visible before exposure to UV light (Fig. 5.14). They printed evenly across the substrate. The colour of the ‘Brown’ stripe was the expected result of mixing the blue of ‘Palatinate Purple’ and the orange of the ‘Flame’ dye (Fig. 5.15). Small fibres within the linen fabric remained white in colour suggesting that this may not have been a pure linen fabric and highlighted that the fibre was not receptive to being printed with photochromic dye. These white flecks may have lightened the overall appearance of the colours of the dyes. When taken indoors, the ‘Brown’ dye faded from brown to blue to orange.

Dye	Development	Fading
‘Aqua Green’	1	1
‘Oxford Blue’	2	2
‘Brown’	3	5
‘Palatinate Purple’	4	3
‘Flame’	5	4

Table 5.3 Development and fading order

Table key

1 = exhibits least of this property (in this case fastest to develop or fade)

5 = exhibits most of this property (in this case slowest to develop or fade)

In this print, the time difference in the development of the dyes, although subtle, was able to be observed, see Table 5.3. Although ‘Brown’ was the third fastest dye to develop, it was the slowest to fade.

Discussion:

As shown in Figure 5.15, the printed stripe colours have been more successful, giving a more cohesive appearance, than the *Bird design*. Although still pale, there is more concentration of colour in the design and no white background to diminish or lighten the appearance of the colours used.

Although the dyes develop very quickly, observing the order of their development was easier in this observation as the dyes were printed side by side. The darker colours appeared to develop more slowly with more dye to ‘fill up’ or ‘fill in’ the colour, possibly as a greater change between the substrate colour and the developed colour is observed. Again, the paler dyes appeared to fade more quickly than the brighter dyes. It was as though there was less dye/colour to drain out of the paler dyes whereas brighter dyes had more colour to fade away. The development and fading times will be measured in future experiments.

The fading time of ‘Brown’ was interesting. It faded more slowly than both ‘Flame’ and ‘Palatinate Purple’. As the unmixed ‘Flame’ faded more slowly than the unmixed ‘Palatinate Purple’ it may have been expected that ‘Brown’ would fade to orange and the blue would not be visible, however this did not occur. Perhaps ‘Palatinate Purple’ was visible because it is a darker colour than ‘Flame’ and the ‘Flame’ dye initially faded more quickly than the ‘Palatinate Purple’, and finally took longer to fade overall. It can be anticipated therefore, that varying the quantities of other dye mixes will give interesting combinations of fade rates and colour effects and these could be exploited.

5.3.4 Photochromic dyes tested on 14 different substrates

The Reversacol dyes used for testing were:

‘Oxford  : ‘Rush 
Blue’ Yellow’

As shown in Section 5.3.1, the fibre composition of the substrate affected the colour of the developed dyes. Additionally, the dyes appeared pale on the silk and linen prints in Section 5.4.2. Therefore, the dyes were printed on a wide selection of fabrics, covering a cross section of qualities and weights, available from the print room. The aim was to establish the substrate on which the dyes developed most strongly, thereby providing the widest possible colour palette so that varying depths of shade could be used.

Synthetic fibre fabrics were now included in the observations to see whether the dyes reacted differently with the colours developing more brightly when printed on these substrates. See Appendix D.1.

Observations:

The following observations were made of the printed samples when they were exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- intensity of colour
- fabric weight

Results:

‘Rush Yellow’ was not visible on any of the substrates before exposure to UV light. The strength of the developed colour varied depending upon the substrate (Figs. 5.16 and 5.17). When developed on cotton drill (Fig. 5.16.b) and silk/viscose velvet (Fig. 5.16.g), it was markedly brighter than on the other fabrics. On the wool serge, which was a darker cream substrate when not printed, the dye developed to an orange/brown colour.

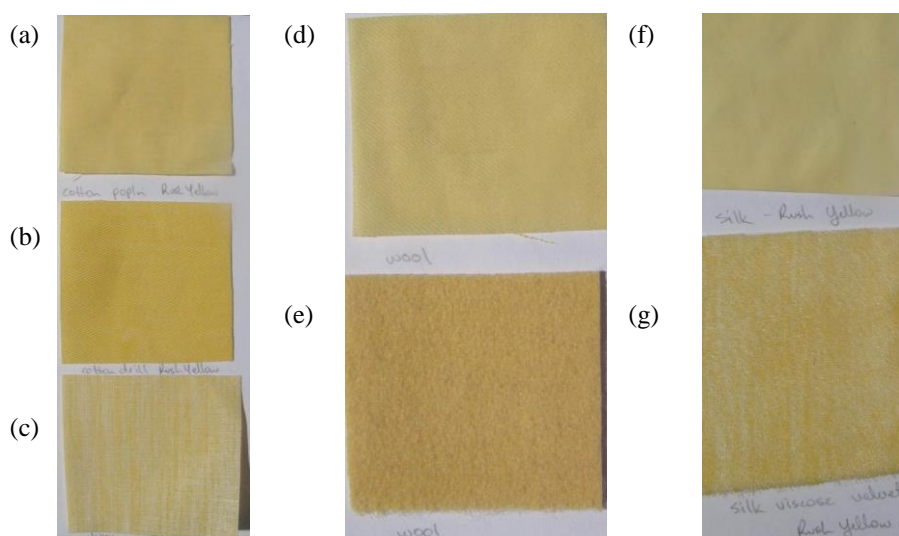


Fig. 5.16 ‘Rush Yellow’ printed on a range of natural fibre substrates

a. Cotton poplin b. Cotton drill c. Linen d. Wool twill e. Wool serge f. Silk g. Silk/viscose velvet

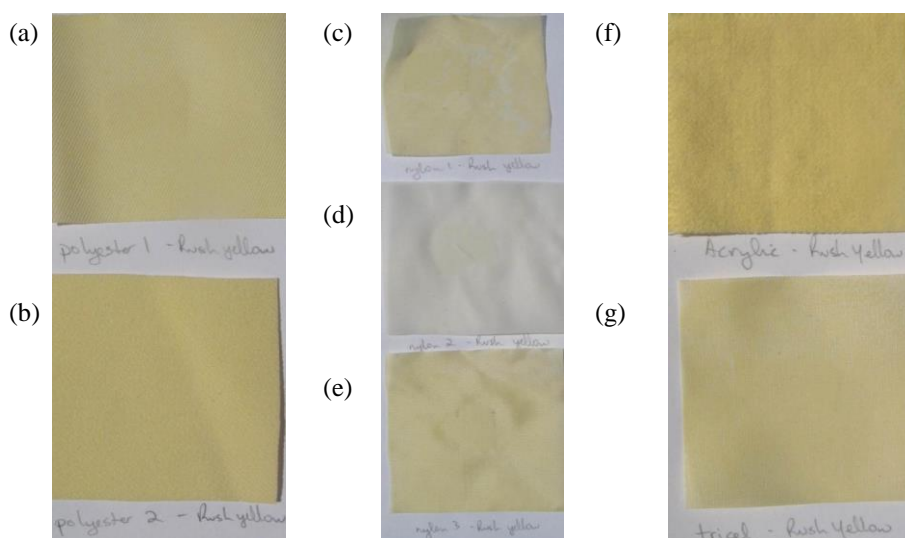


Fig. 5.17 'Rush Yellow' printed on a range of synthetic fibre substrates

a. Polyester 1 b. Polyester 2 c. Nylon voile d. Nylon 1 e. Nylon 2 f. Acrylic g. Tricel

'Oxford Blue' was not visible on any of the substrates before exposure to UV light. When developed it was light blue, appearing rather pale in colour. The strength of the developed colour varied depending upon the substrate (Figs. 5.18 and 5.19). When developed on cotton drill (Fig. 5.18.b) and silk/viscose velvet (Fig. 5.18.g), it was markedly brighter and had more depth of colour than when developed on the other fabrics.

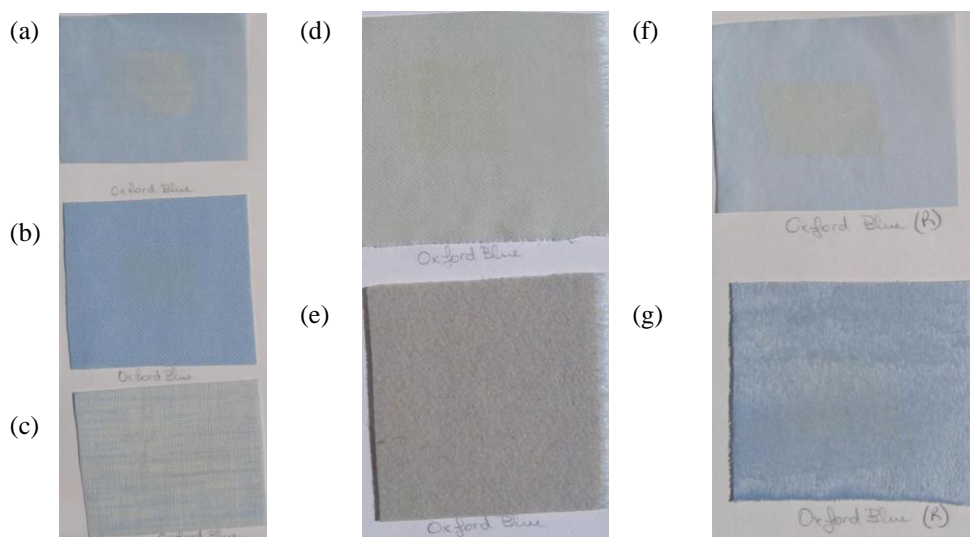


Fig. 5.18 'Oxford Blue' printed on a range of natural fibre substrates

a. Cotton poplin b. Cotton drill c. Linen d. Wool twill e. Wool serge f. Silk g. Silk viscose velvet

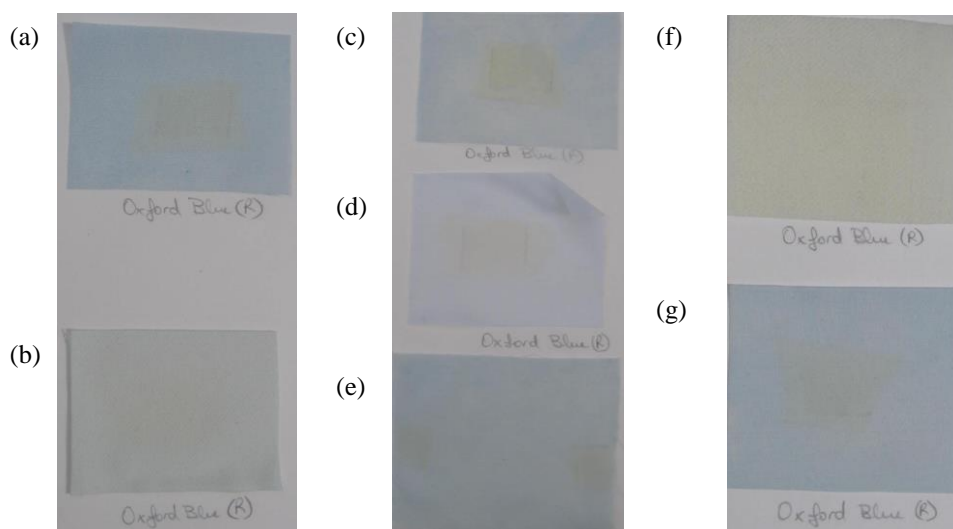


Fig. 5.19 'Oxford Blue' printed on a range of synthetic fibre substrates

a. Polyester 1 b. Polyester 2 c. Nylon voile d. Nylon 1 e. Nylon 2 f. Acrylic g. Tricel

The following list shows the intensity of the colours of the two dyes when printed on natural and synthetic fibre fabrics and developed by natural UV light.

Dye	Fabric	Dye	Fabric
'Rush Yellow'		'Oxford Blue'	
1	Nylon 1	1	Nylon 1
2	Nylon voile	2	Acrylic
3	Nylon 2	3	Polyester 2
4	Tricel	4	Wool twill
5	Polyester 1	5	Wool serge
6	Polyester 2	6	Linen
7	Silk	7	Nylon voile
8	Linen	8	Nylon 2
9	Acrylic	9	Silk
10	Wool twill	10	Cotton poplin
11	Cotton poplin	11	Polyester 1
12	Wool serge	12	Tricel
13	Silk/viscose velvet	13	Silk/viscose velvet
14	Cotton drill	14	Cotton drill

Table 5.4 The intensity of colour of the dyes when printed on natural and synthetic fibre fabrics

Table key:

1 = exhibits least of this property (in this case the palest)

14 = exhibits most of this property (in this case the brightest)

As shown in Table 5.4, the colour of the developed dyes was overall the palest on the synthetic fibre fabrics and the strongest/brightest on the natural fibre fabrics.

Fabric	Weight
Silk	1
Cotton poplin	2
Silk/viscose velvet	3
Linen	4
Wool twill	5
Cotton drill	6
Wool serge	7

Table 5.5 Weight of natural fibre fabrics

Fabric	Weight
Nylon voile	1
Nylon 1	2
Nylon 2	3
Tricel	4
Polyester 1	5
Acrylic	6
Polyester 2	7

Table 5.6 Weight of synthetic fibre fabrics

Table key

1 = exhibits least of this property (in this case the lightest)

7 = exhibits most of this property (in this case the heaviest)

Based on their weight, see Tables 5.5 and 5.6, the handle of the range of fabrics printed with ‘Rush Yellow’ and ‘Oxford Blue’ would make them suitable for use within interior design applications. The heavier fabrics would have a firmer drape than the lighter ones. Certain fabrics may be chosen for softness. However, dye performance would predominantly determine the final choice of fabric substrate, combined with the way in which the substrate is used in conjunction with the artificial light source.

The Reversacol dyes used for testing were:

‘Aqua  : ‘Cardinal’  : ‘Flame’  : ‘Palatinate 
Green’ Purple’

Based on analysis of the observations noted above, i.e., colour intensity and fabric drape and handle, the substrates were narrowed down to three and further observations made. See Appendix D.2.

Observations:

The following observations were made of the printed samples when they were exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- intensity of colour
- fading order

‘Palatinate Purple’ was not visible on any of the substrates before developing. As shown in Figures 5.20-5.23, each of the dyes developed to a similar shade on both the cotton poplin and the cotton drill. However, on the wool twill the colour of each of the dyes noticeably changed. ‘Aqua Green’ and ‘Palatinate Purple’ each appeared a shade of green (Figs. 5.20 and 5.23). ‘Cardinal’, which developed to a shade of dark pink on both cotton substrates, appeared a salmon colour on the wool twill (Fig. 5.21). Whereas ‘Flame’ developed to a burnt orange colour on cotton drill, it became more golden in colour on the wool twill (Fig. 5.22).

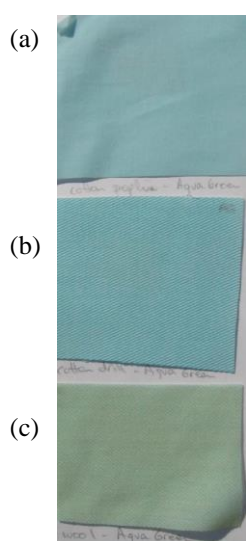


Fig. 5.20 ‘Aqua Green’
a. Cotton poplin b. Cotton drill c. Wool twill

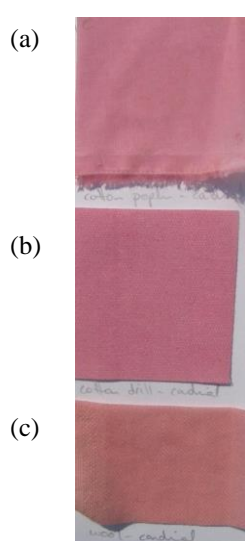


Fig. 5.21 ‘Cardinal’

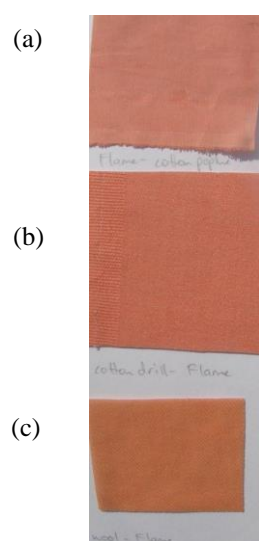


Fig. 5.22 ‘Flame’

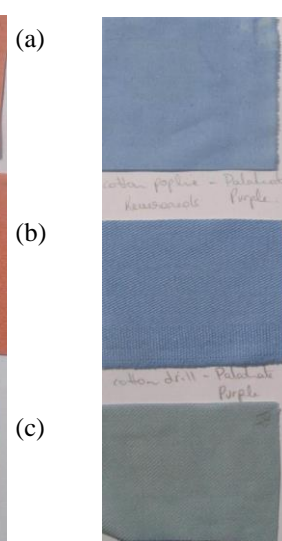


Fig. 5.23 ‘Palatinate Purple’

As shown in Figs. 5.16 and 5.18, ‘Rush Yellow’ and ‘Oxford Blue’ both developed noticeably more strongly on the cotton drill than the wool twill. A comparison of the strength of colour of ‘Aqua Green’, ‘Cardinal’, ‘Flame’ and ‘Palatinate Purple’ on the three substrates was made. All of the dyes developed most strongly/brightly on cotton drill, see Table 5.7.

Dye	Fabric		
	Cotton drill	Cotton poplin	Wool twill
‘Aqua Green’	3	2	1
‘Cardinal’	3	2	1
‘Flame’	3	2	1
‘Palatinate Purple’	3	2	1

Table 5.7 The intensity of colour of the dyes on three substrates

Table key:

1 = exhibits least of this property (in this case the palest)

3 = exhibits most of this property (in this case the brightest)

A comparison between the strength of the colours of the six dyes as they developed on the cotton drill was made, see Table 5.8. The results were consistent with those observed in Section 5.3.1, Table 5.2, when the dyes developed on crinkle cotton, with the exception of ‘Palatinate Purple’, that now appeared to develop more deeply than ‘Flame’.

Dye	Intensity of colour
‘Oxford Blue’	1
‘Aqua Green’	2
‘Cardinal’	3
‘Rush Yellow’	4
‘Flame’	5
‘Palatinate Purple’	6

Table 5.8 Intensity of colour

Dye	Fading order
‘Oxford Blue’	1
‘Aqua Green’	2
‘Palatinate Purple’	3
‘Rush Yellow’	4
‘Flame’	5
‘Cardinal’	6

Table 5.9 Fading order

Table key

1 = exhibits least of this property (in this case the palest or the fastest)

6 = exhibits most of this property (in this case the brightest or the slowest)

Photochromic dyes have different speeds of development and fading, with the development times much shorter than the fade times. On average, fade times are two or three times longer than development times with some of the dyes fading in several seconds, whilst others can take several minutes [5.8]. To the naked eye, however, any difference in development time was difficult to discern, with all of the dyes appearing to have developed fully within 10 seconds. The dyes were then taken indoors, i.e., removed from natural UV light. Their order of fading on the cotton drill was observed and compared, see Table 5.9. The brighter dyes appeared to fade more slowly than the paler dyes.

Discussion:

There was consistency in the performance of the colours of the dyes on both cotton drill and cotton poplin. Additionally, there was consistency in the unusual result of the four dyes on the wool twill. It was noted that the unusual result occurred on wool, an animal fibre. This difference in colour looks effective when the wool fabrics are placed side by side with the cotton fabrics. This diversity could be exploited in various ways. For example, the wool twill and the cotton could be woven in a cloth together. If the weave structures were planned to fit in with the overall design, and a design then printed on this woven fabric, the developed dyes on the printed wool would provide additional

colours, as well as a different texture, giving another creative aspect to the design. This would be an interesting area for future research.

In Table 5.2, 'Flame' appeared to develop more intensely than 'Palatinate Purple'. However, this order was reversed in Table 5.8 with 'Palatinate Purple' appearing the stronger coloured dye. This is an example of the subjective aspect of working with the dyes.

It appeared that the brighter coloured dyes faded more slowly than the paler coloured dyes. This information, coupled with the variations in speed of fading, will affect the choice of colours used, the colour combinations and their placement within a design.

5.3.5 *Trees and circles*

The Reversacol dyes used for testing were:

'Aqua Green' : 'Cardinal' : 'Flame' : 'Oxford Blue' : 'Palatinate Purple' : 'Rush Yellow'

Pigments used for testing were:

'Imperon Blue KRR' : 'Imperon Orange KRL' : 'Imperon Red KGR' : 'Imperon Yellow KR'

Basic designs were printed to observe the movement of the dyes as they interacted within simple imagery, i.e., apples and leaves on a tree. Simple shapes were used to create a shadow effect using circles and stripes. The relationship the dyes have with stationary pigments was also observed. See Appendix E.

Observations:

The following observations were made of the printed fabrics when exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- the resulting colour when photochromic dyes are printed one on top of the other
- the resulting colour when photochromic dyes are printed on top of pigments
- the effect of the movement of photochromic dyes beside and within another photochromic dye
- the effect of the movement of photochromic dyes beside and within pigments

- time taken for the motifs to develop in comparison with one another and the visual effect this generates

Results:



Fig. 5.24 Undeveloped 'Aqua Green' and 'Cardinal' dye

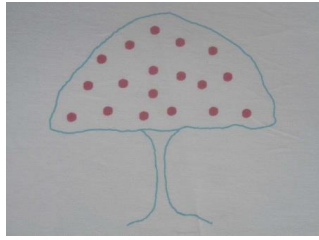


Fig. 5.25 Developed 'Aqua Green' and 'Cardinal' dye



Fig. 5.26 Green pigment, undeveloped 'Cardinal' dye

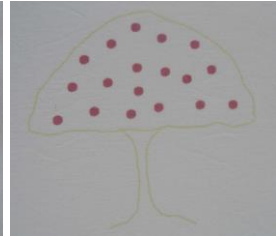


Fig. 5.27 Developed 'Cardinal' dye



Fig. 5.28 Undeveloped 'Aqua Green' dye



Fig. 5.29 Developed 'Aqua Green' dye



Fig. 5.30 Green pigment, undeveloped 'Cardinal' Dye

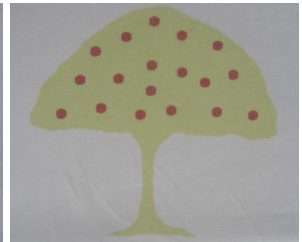


Fig. 5.31 Developed 'Cardinal' dye



Fig. 5.32 Green pigment, undeveloped 'Aqua Green' dye



Fig. 5.33 Developed 'Aqua Green' dye



Fig. 5.34 Red pigment, undeveloped 'Cardinal' dye



Fig. 5.35 Developed 'Cardinal' dye



Fig. 5.36 Red pigment, undeveloped 'Rush Yellow' dye



Fig. 5.37 Developed 'Rush Yellow' dye



Fig. 5.38 Undeveloped 'Flame' and 'Cardinal' dye



Fig. 5.39 Developed 'Flame' and 'Cardinal' dye



Fig. 5.40 Orange pigment, undeveloped 'Cardinal' dye



Fig. 5.41 Developed 'Cardinal' dye

The following results were observed:

- The white pigment binder was visible on the substrate from certain angles and on certain prints (Fig. 5.28).
- There was no base colour from any of the dyes visible on the fabric.
- All of the images printed evenly. The colours of the dyes were crisp and clear on the cotton drill substrate and showing the same hues as in previous samplings.
- In areas where photochromic dye overlapped with photochromic dye and photochromic dye and pigment overlapped, the resulting colour when the dyes developed was a combination of those two colours, as would be expected when mixing standard dyes or paints (Figs. 5.31, 5.33, 5.35, 5.37, 5.39 and 5.41).
- The movement of photochromic dyes beside and within another photochromic dye can be seen with 'Cardinal' and 'Aqua Green' (Fig. 5.25) and 'Flame' and 'Cardinal' (Fig. 5.39). The brighter 'Cardinal' dye appeared to develop more quickly than the paler 'Aqua Green' dye. The 'Flame' and 'Cardinal' appeared to develop at a similar rate with the eye drawn back and forth from one colour to the other. The subtle difference in the development of the colours gives the image a subtle floating presence.
- The movement of the photochromic dyes can be seen more clearly when they are printed beside or within the static 'Green' pigment (Figs. 5.27, 5.31 and 5.33), 'Imperon Red KGR' pigment (Figs. 5.35 and 5.37) and 'Imperon Orange KRL' pigment (Fig. 5.41) with the static permanent dye working as an anchor.
- When the circles printed with photochromic dye became visible as they overlapped the circles printed with static pigment, they showed the potential for the creation of shadows. The circles printed with the similar shades of

‘Cardinal’ and ‘Imperon Red KGR’ (Fig. 5.35) appeared more effective in this way than the contrasting ‘Rush Yellow’ and ‘Imperon Red KGR’. As the circles printed with photochromic dye developed beside the moving straight lines (Fig. 5.39) and the static straight lines (Fig. 5.41) both gave reference to 3D imagery, however when both motifs move (Fig. 5.39) the image appears more ephemeral and less grounded.

- The similar colours of ‘Flame’ and ‘Imperon Orange KRL’ show how photochromic colour could be used to fill in an image, or develop to create a totally different image, even though using the same colour.
- The movement of a single solid colour, even in a recognisable motif (Fig. 5.29), has less impact than an image with two moving dyes (Fig. 5.25) or one moving and one static dye (Fig. 5.27) even though the amount of moving colour is proportionally smaller.
- On a rainy day the prints were observed under UV light tubes. Thereafter, the ‘Cardinal’ dye appeared pale yellow and the ‘Flame’ appeared pale pink when the dyes were at rest (Fig. 5.38).

Discussion:

The image of a tree with apples emerging from the background may have drawn the viewer’s eye to the colour of the ‘Cardinal’ dye, explaining the observation that it developed more quickly than the paler ‘Aqua Green’ dye (Fig. 5.25). This image, although very simple, was interesting and exciting to observe, showing the potential the dyes may have for changing imagery.

Images that show more than one motif, or more than one part of a motif, moving appear to have more visual impact than a single motif moving on its own. The potential for the dyes to create 3D imagery would be interesting to explore, particularly with the incorporation of shadow. Pigment, as a permanent colour, appears to act as an anchor within the imagery just as, for example, a house is immovable and the shadow that it creates moves around it.

When two photochromic dyes interact together, both moving as they develop and fade and also sit in that less defined space in between, they show, in the broadest sense, the potential for a more ‘other worldly’ image, something more ethereal and ephemeral, to be created.

Images in this set of observations used fine lines and small motifs. This enabled colours and interactions to be noted, however the *Stripe design*, in Section 5.3.3, with colour covering the whole substrate, enabled interactions to be watched more closely. Therefore in the next set of samples, colour will cover the whole surface.



The staining by ‘Cardinal’ and ‘Flame’, as can be seen in Figures 5.34 and 5.38, caused by the UV light tubes, will need to be considered in future observations and design work.

5.3.6 Abstract shapes

The Reversacol dyes used for testing were:

‘Aqua Green’  : ‘Cardinal’  : ‘Palatinate Purple’ 

Pigments used for testing were:

‘Imperon Red KGR’  : ‘Imperon Yellow KR’ 

A random selection of photochromic dyes and pigments were printed on top of one another and side by side in simple stripe and scribble designs so that developed colour covered the whole surface of the substrate. These more abstract images would enable colour behaviours to be observed with less distraction than in the more pictorial imagery that appears to hint at something else occurring. See Appendix F.

Observations:

The following subjective observations were made of the printed fabrics when they were exposed to natural UV light:

- colour of print when dyes not developed
- colour of print when dyes developed/actual hue
- the resulting colour when photochromic dyes are printed on top of, and beside one another
- the resulting colour when photochromic dyes are printed on top of, and beside pigments
- the effect of the movement of photochromic dyes beside and within another photochromic dye
- time taken for the motifs to develop in comparison with one another and the visual effect this generates

Results:



Fig. 5.42 Undeveloped 'Aqua Green' and 'Cardinal' dye



Fig. 5.43 Developed 'Aqua Green' and 'Cardinal' dye



Fig. 5.44 Undeveloped 'Cardinal' and 'Palatinate Purple' dye



Fig. 5.45 Developed 'Cardinal' and 'Palatinate Purple' dye



Fig. 5.46 Red pigment, undeveloped 'Palatinate Purple' dye

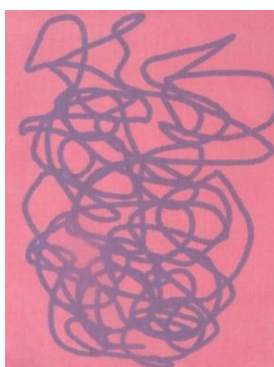


Fig. 5.47 Developed 'Palatinate Purple' dye



Fig. 5.48 Red pigment, undeveloped 'Aqua Green' dye

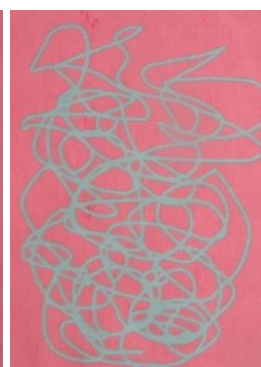


Fig. 5.49 Developed 'Aqua Green' dye



Fig. 5.50 Yellow pigment, undeveloped 'Palatinate Purple' dye



Fig. 5.51 Developed 'Palatinate Purple' dye

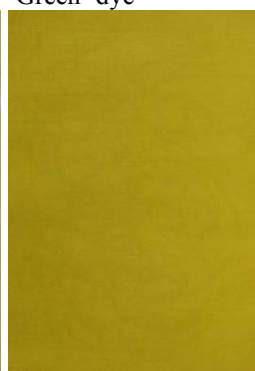


Fig. 5.52 Yellow pigment, undeveloped 'Palatinate Purple' dye



Fig. 5.53 Developed 'Palatinate Purple' dye



Fig. 5.54 Yellow pigment, undeveloped 'Palatinate Purple' dye

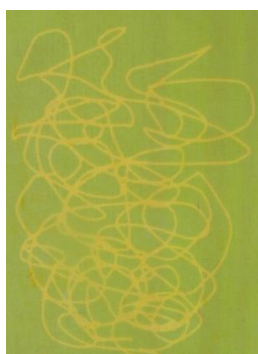


Fig. 5.55 Developed 'Palatinate Purple' dye



Fig. 5.56 Undeveloped 'Aqua Green' and 'Palatinate Purple' dye



Fig. 5.57 Developed 'Aqua Green' and 'Palatinate Purple' dye



Fig. 5.58 Undeveloped 'Aqua Green' and 'Cardinal' dye



Fig. 5.59 Developed 'Aqua Green' and 'Cardinal' dye

The following results were observed:

- The white pigment binder was visible on the substrate from certain angles, see Figure 5.44.
- All of the images printed evenly. The colours of the dyes were crisp and clear on the cotton drill substrate and showing the same hues as in previous samples.
- In areas where photochromic dye overlapped with photochromic dye and photochromic dye and pigment overlapped, the resulting colour when the dyes developed was a combination of those two colours, as would be expected when mixing standard dyes or paints (Figs. 5.47, 5.51, 5.53 and 5.55)
- Photochromic dye on photochromic dye = dull colour (Figs. 5.43, 5.45, 5.57)
- Photochromic dye on pigment = dull colour (Figs. 5.47, 5.53)
- Photochromic dye beside photochromic dye = luminous colour (Fig. 5.59)
The developed 'Cardinal' dye looked quite vibrant, appearing lighter and separate from the background colour of 'Aqua Green', appearing to hover a little above it.
- Photochromic dye beside pigment = luminous colour (Fig. 5.49)
- Photochromic dye on pigment with photochromic dye in space = luminous photochromic colour in space
- Undeveloped photochromic dye appeared as a crisp contrast beside the printed pigment (Fig. 5.48 and 5.50).
- Printing a design using a photochromic dye of one colour on top of a pigment background of another colour resulted in a change of background colour and a new visible design when the photochromic dye developed (Fig. 5.55).
- As in Section 5.4.3, the static permanent colour seemed to serve as an anchor to the design with the eye being drawn to the moving colour.

- In Figures 5.43 and 5.59 the ‘Cardinal’ colour had greater presence than the ‘Aqua Green’ colour and appeared to develop more quickly.
- The ‘Palatinate Purple’ dye appeared to develop more quickly than the ‘Cardinal’ dye in Figure 5.45, however the ‘Aqua Green’ appeared to develop more quickly than the ‘Palatinate Purple’ (Fig. 5.57)
- As in Section 5.3.5, these prints were also developed under UV light tubes on a rainy day. Again, the ‘Cardinal’ dye stained the substrate a pale yellow after it had been developed by the artificial UV light.

The photos of the undeveloped images were taken indoors and the photos of the developed images were taken outdoors in sunlight. This accounts for the difference in the colour of the pigment in these photographs.

Discussion:

It was easier to observe the actual photochromic colours as they were developing, and also their movement, in these less pictorial designs as there was less interplay between image and colour. The scribble and stripes proportionately covered a larger surface area than the fine line and small motif in Section 5.3.5. This may also have contributed to the perceived ability to observe interactions more easily.

As has been shown, when photochromic dyes are combined with, or placed beside, another photochromic dye, and combined with or placed beside a pigment, the resulting colours display varying degrees of clarity and luminosity. These colour effects could be used to help create the overall atmosphere of a design, whether it was one of brightness or dullness. A complete change in the colour visible and the appearance of a design can also occur when the photochromic dye is hidden within a pigment substrate. When the photochromic dye develops a totally new image on a different coloured background appears, as in Figure 55. Controlling the development of the dyes when using a variety of colour mixes and considered motif placement may enable a design of great complexity to be built. It will be interesting to observe the capacity of photochromic dyes to be used within a design with the colours appearing and disappearing at different intervals and speeds.

The luminous quality of ‘Aqua Green’ when it is placed beside ‘Imperon Red KGR’, shown in Figure 5.49, may be enhanced because the two colours sit opposite one

another on the colour wheel (Fig. 4.2). It may also be why ‘Cardinal’, a shade of red, appeared to hover above ‘Aqua Green’.

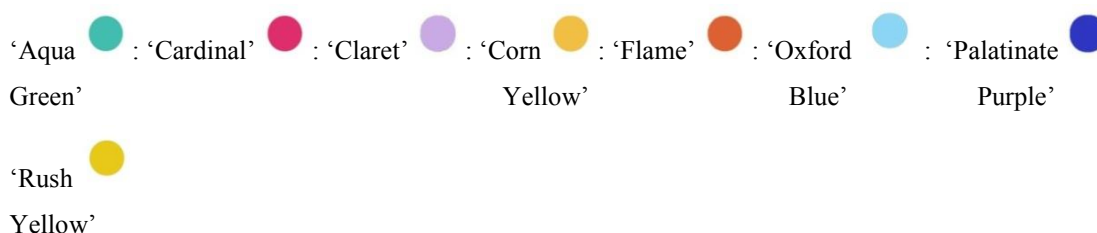
Before the photochromic dyes have been developed the substrate is either white or very pale. After continuous handling, small marks that would ordinarily be inconsequential now mar the substrate. Their impact would depend upon the size of the substrate and its closeness to the viewer. This undesirable effect may be prevented by wearing latex gloves.

5.4 Colour Interactions

The following sets of observations look at the colour interactions of the dyes with pigments and with one another. Traditional methods for colour observation, such as those used for permanent dyes were considered. These could not be applied though, as the actual colour and movement of photochromic dyes is affected by atmospheric conditions, and, more importantly, is not fixed. However, borrowing from traditional dye colour theory, the dyes were printed in squares, thereby lessening the influence of any pictorial imagery, to observe their development and fading in combination, observe colour effects when printed on ‘half’ and ‘full’ strength pigments and to note any further idiosyncracies that the dyes may exhibit. The interactions of only two colours in combination were observed at this stage.

5.4.1 *Printing photochromic dyes on pigment*

The Reversacol dyes used for testing were:



Pigments used for testing were:



The dyes have previously been used on t-shirts and fashion garments in combination with permanent dyes (Figs. 1.24 and 1.26 in Chapter 1). As shown in Fig. 5.55, using photochromic dye and pigment together enables a totally new design in a new colour to be created. Therefore, photochromic dyes were printed on top of different strengths of

pigment to observe the colours produced. The primary colours of red, yellow and blue were specifically chosen as base colours because they cannot be created through the mixing of other colours. See Appendix G.

Observations:

The following observations of the dyes were made when they were exposed to natural UV light:

- colour development
- colour combinations
- scale
- fading

Results:

Depending upon the particular colour combinations, the photochromic dye ranged from being not visible at all or barely visible to being noticeable, appearing as a stain on the pigment, or clearly visible before developed by sunlight.

The dyes appeared to noticeably ‘fill up’ within 10 seconds (with any further colour development occurring more slowly and subtly thereafter) with the colours progressively changing, some developing more obviously and quickly than others, depending upon the dye.

As with mixing paints, the resulting colour of the pigment and dye combinations depended upon the colours used. Either a very definite distinctive colour was created or a muddy colour (brown or grey in shade) appeared. This muddier colour often appeared to be only a varying shade of the pigment substrate when it was observed in isolation, whereas it contrasted with the base pigment when observed in place beside it, just as placement and colour combinations usually influence the colour we see. Additionally, the four colours (half and full strength pigment and the two resulting colours produced by the combination of photochromic dye and either strength of pigment) either harmonised well with very similar tones (Figs. 5.60-5.61) or appeared as very distinct contrasts with one another, as shown in Figures 5.62-5.63.

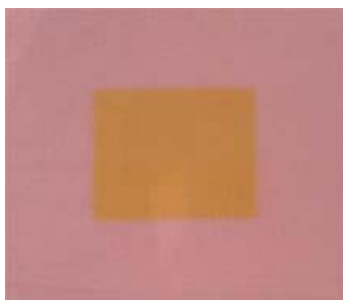


Fig. 5.60 Developed 'Rush Yellow' on half strength red pigment



Fig. 5.61 Developed 'Rush Yellow' on full strength red pigment



Fig. 5.62 Developed 'Flame' on half strength blue pigment



Fig. 5.63 Developed 'Flame' on full strength blue pigment

The strength of colour of the developed dyes when printed on the larger-sized samples was also noted. Ultimately, if the photochromic colours used in the project are bright, smaller images may be effective. Alternatively, lighter colours may need a larger scale of image so they can actually be seen and are able to create visual impact.

Observing the colours fading necessitated moving the printed samples indoors. During this time the photochromic dyes progressively faded into the pigment background. A closer study of the fading of the dyes will take place in subsequent observations. As with previous samples, the difference in the colour of the pigment in these photos depended upon whether the photos were taken indoors or outdoors.

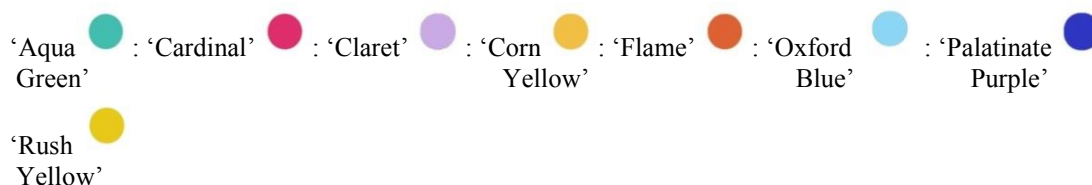
Discussion:

Depending upon the design to be produced, if the dyes were to be developed by the sun, their exposure to this light would be over the day time period, generally hours, regardless of season, with the weather conditions affecting the resulting display. It has also been shown that, when using sunlight to develop the dyes they pass through changes, albeit quickly, until reaching a particular colour. They then need to be physically removed from the sunlight, or the sunlight needs to be removed from them, for the colours to fade. When combinations of photochromic dyes are used in sunglasses, this progressive change in colour is undesirable therefore dyes with similar fade rates are used [5.9]. However, in a design context, these differences may be

exploited. Additionally, if the dyes were in an environment where their exposure to UV light was more controlled, a degree of mastery over their development and fading may be more achievable, and therefore their potential for creating patterns also more refined.

5.4.2 *Printing photochromic dyes side by side*

The Reversacol dyes used for testing were:



Following on from the previous set of observations, the dyes were printed to observe the visual effect created by two blocks of 'moving' colour placed side by side. See Appendix H.

Observations:

The following observations of the dyes were made when they were exposed to natural UV light:

- colour development
- colour combinations
- scale
- fading

Results:

'Aqua Green' and 'Oxford Blue' were clearly the lighter coloured dyes. 'Palatinate Purple' was not visible on the fabric before developing. It then coloured up through very pale green to aqua, to light blue and finally to blue.

The darker colours seemed to develop more quickly than the lighter ones. For example, 'Palatinate Purple' appeared to develop more quickly than 'Rush Yellow'. This was contrary to earlier observations where the darker colours appeared to develop more slowly as they 'filled up', as previously described in Section 5.3.3, and may be because the eye is drawn to their stronger colour. Their movement and the change they go through from base colour to developed colour appears visually to be greater than the change of developing paler coloured dyes.

The lighter and the stronger colours contrasted brightly with one another. As the stronger colours developed they often drew attention to themselves when placed beside a lighter developing dye. When dyes, such as 'Flame' and 'Cardinal', that are of a similar intensity were developing, the eye was evenly drawn from one to the other as shown in Figure 5.64. However, 'Flame' and 'Corn Yellow' seemed to actually vie for attention, as they developed in intensity side by side (Fig. 5.65).



Fig. 5.64 'Flame' and 'Cardinal' dye



Fig. 5.65 'Flame' and 'Corn Yellow' dye

When the inside square was a darker colour it appeared to hover a little above the lighter surrounding colour. For example, 'Flame', 'Palatinate Purple', 'Corn Yellow' and 'Cardinal', all appearing to sit above the surrounding 'Rush Yellow', were reminiscent of Mark Rothko's paintings where he places blocks of permanent colour in such combinations and proportions that they float, balance and hold one another creating shifting colour relationships on a static canvas, as shown in Section 4.3.3.

As the lighter, faster fading dyes receded within the brighter, slower fading ones, they were suggestive of the works of the painter Howard Hodgkin, and the depth he was able to show within his pictures, as shown in Section 4.3.4, Figure 4.38. For example, the paler dyes of 'Aqua Green' and 'Oxford Blue' both faded to white in amongst the pale yellow of 'Rush Yellow'. 'Oxford Blue' faded and left a 'hole' in the 'Flame'. 'Aqua Green' faded more quickly than the surrounding 'Palatinate Purple' leaving a white square in amongst a fading very pale green colour.

The outer 'Palatinate Purple' faded more quickly than the 'Cardinal', fading back to light green, leaving a slower fading pink square in the centre. Initially 'Flame' seemed to fade more quickly than the inner 'Cardinal' square, however then the 'Cardinal' appeared to fade more quickly than the 'Flame'. Perhaps 'Flame' initially fades quickly then slows down as it loses colour.

It was noticeable that placing the colours in the larger-sized samples, with a square within a square, enabled the colour interactions to be more easily observed.

Discussion:

The movement of photochromic dyes beside photochromic dyes appeared more organic than photochromic dyes beside pigments. It also enabled more than just a colour interaction to be presented. As the dyes develop or fade in their differing colours the illusion of depth is created on a flat surface. This is achieved by the action of the dyes combined with the individual colours they carry, with the latter very much influencing the dynamic. There is also depth present as a colour appears and develops and grows, as though it is moving forwards, and as a colour fades and recedes, moving backwards.

Based on the above observations, there is the potential for creating moving paintings, referencing Hodgkin and Rothko, or moving pictures, or something that sits in between. The capacity of the dyes to do this and how closely they sit towards either end of this spectrum will be explored in Chapter 8.

5.4.3 *Fading strips*

The Reversacol dyes used for testing were:



As shown in previous tests, different dyes fade at different rates. To utilise the colours of the dyes effectively their fading order needed to be established. See Appendix I.

Observations:

The following observations were made:

- fading order
- general fading times

Results:



Fig. 5.66 Initial placement of printed dyes developing in sunlight for one minute

Dye	Fading order
'Oxford Blue'	1
'Plum Red'	2
'Aqua Green'	3
'Claret'	4
'Palatinate Purple'	5
'Sea Green'	6
'Rush Yellow'	7
'Volcanic Grey'	8
'Midnight Grey'	9
'Cardinal'	10
'Corn Yellow'	11
'Flame'	12

Table 5.10 Fading order of printed dyes developed in sunlight

Table key

1= exhibits least of this property (in this case fastest to fade)

12 = exhibits most of this property (in this case slowest to fade)



Fig. 5.67 Printed dyes arranged according to their order of fading, see Table 5.10, and developed in sunlight for one minute.

The progressive fading of the dyes is illustrated in Figures 5.68-5.70. 'Oxford Blue', 'Plum Red', 'Aqua Green', 'Claret' and 'Palatinate Purple' faded the most quickly, losing most of their colour within 25 seconds, as shown in Figure 5.68. This group was followed by 'Sea Green' and 'Rush Yellow', whilst 'Volcanic Grey', 'Midnight Grey', 'Cardinal', 'Corn Yellow' and 'Flame' lingered, taking longer to fade (Fig. 5.69). However, within these five slower fading dyes, there was also a demarcation between the fading of 'Volcanic Grey' and 'Midnight Grey' and the remaining three dyes, i.e., 'Cardinal', 'Corn Yellow' and 'Flame' (Fig. 5.70).

All of the dyes continued to slowly fade and were observed until there was minimal colour on the substrate, i.e., for approximately 11 minutes.



Fig. 5.68 Printed dyes after 25 seconds fading indoors



Fig. 5.69 Printed dyes after one minute fading indoors



Fig. 5.70 Printed dyes after three minutes fading indoors

According to their manufacturers, the fade back of the dyes occurs in two stages. An initial stage is where 90% of the colour fades and the remaining 10% of colour lingers for a longer period of time [5.10]. This is most obviously evident with ‘Cardinal’, ‘Corn Yellow’ and ‘Flame’ as, after initially losing the strength of their colour, these dyes took longer to lose their remaining colour. This may also explain the fading of ‘Flame’ and ‘Cardinal’ in Section 5.4.2.

It can be seen that the colours of the faster fading dyes, on the right-hand side of Figure 67 are from the range of blue and purple coloured dyes. The slower fading dyes, on the left-hand side of the picture, are from the range of yellows and oranges. The grey dyes appear to sit between both ends of the spectrum.

The intensity of colour is not confined to a slower or a faster fading dye. For example, of the brighter dyes, ‘Plum Red’ was the fastest to fade, ‘Palatinate Purple’ and ‘Sea Green’ are in the middle of the fading order whilst Flame is the slowest fading dye.

‘Palatinate Purple’ faded from darker blue, through lighter shades of blue to pale green. ‘Cardinal’ faded more slowly and progressively than the ‘Palatinate Purple’ and from dark pink to salmon to a dark cream colour.

Discussion:

These observations show clearly the staggered effect of fading, a gradation that can valuably be experimented with for the changing of imagery.

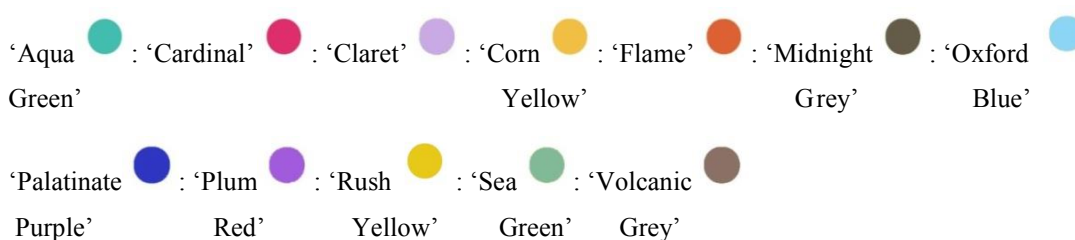
The shades of colour that the speeds of fading correlate with, i.e., blues and purples fading more quickly than the yellows and oranges, will provide a basis for and guide initial design experimentation, coupled with the findings of the colour research of Chapter 4.

The colour changes that ‘Palatinate Purple’ and ‘Cardinal’ go through as they fade will need to be incorporated into designs.

Although all of the dyes fade back to being invisible, or very nearly invisible, they display varying shades of a very pale colour for varying periods of time during this process. The effect the visibility of this pale colour would have in amongst brighter dyes, that are moving as they are being developed and as they are fading, may be insignificant. The presence of a very slowly fading pale colour in the background may provide some subtle spacial depth whilst movement with more prominent colours is occurring and contribute to an overall atmosphere, as opposed to the effect that a white or very pale stationary colour would give to the background.

5.4.4 Mixing photochromic dye colours by printing

The Reversacol dyes used for testing were:



As shown in previous tests, photochromic dyes produce additional colours by mixing, both prior to printing and by printing. Observing the combined dyes as they develop

and fade in sunlight would show general trends in their response to the presence and absence of UV light. This information would serve as a baseline for when the dyes are developed by an artificial UV light source. Although not a detailed colour study, the observations would also allow any idiosyncracies to be observed. See Appendix J.

Observations:

The following observations were made:

- resulting colour of the combined dyes when they had developed
- visual colour effects of the dyes as they faded

Results and Discussion:

When the first layer of dyes had been printed, dried in the oven and cooled, they were not visible on the substrate. When the second layer of dyes had been printed, dried in the oven, baked and cooled the base colour became and remained lightly visible.

The resulting developed colours were a combination of both dyes. Their fading order was in keeping with the results of Section 5.4.3, and reflected in the visual effects created. For example, if both dyes were slow fading there was a progressive fading of the combined colour. If there was a noticeable difference in their fading times, the faster fading dye of the pair would disappear from view leaving the remaining colour of the slower fading dye still visible on the substrate. For example, in the combination of 'Flame' and 'Plum Red' the change is quite immediate as the fast fading 'Plum Red' dye disappears.

The impact of the stronger coloured faster fading dyes was noticeable. For example, 'Sea Green' was dominant when combined with 'Flame' and observed outdoors in the sun. When removed from the sun, the impact of the green colour lessened and the mix became browner in colour. This is in keeping with 'Sea Green' being a faster fading dye than 'Flame'. At times the remaining colour appeared to be tinged with a hint of the faster fading dye.

The colour of the slower fading dye affected the pairings. For example, 'Midnight Grey' is a darker grey than 'Volcanic Grey' and slower fading. When combined with 'Corn Yellow' it impacted on the colour combination and some residual grey remained. As 'Corn Yellow' is of a stronger intensity than 'Volcanic Grey', it dominated the

colour combination. Although 'Corn Yellow' was tinged with 'Volcanic Grey', this eventually disappeared. These results reflect the fading speed and the colour intensity of the dyes. Some of these observations are very subtle and may be inconsequential within a design in which the colours are moving as they develop and fade.

The colours of 'Palatinate Purple', 'Claret', 'Aqua Green' and 'Plum Red' disappeared almost immediately they were removed from sunlight and the impact on each colour combination was dramatic. Immediately the light source was removed the fade back reaction of the dyes began and was visibly evident as the colour could be seen draining from the dyes.

Allowance needs to be given when looking at the colours of the dyes in the photographs as the dyes began to fade immediately they were removed from the sunlight. The initial time period of 10 seconds, from when the first photograph was taken outdoors until the first photograph was taken indoors, was double the five second intervals in which the photographs were taken thereafter. During this initial removal from the light source, when the fade back reaction begins, the colour loss from the dyes appears to be at its most pronounced.

The impact of 'Oxford Blue' in a combination was very small, or negligible, as to be expected from a pale and fast fading dye.

The impact of 'Palatinate Purple' (seen as dark blue) was noticeable in all combinations as it is such a strong colour. When combined with 'Corn Yellow' it was expected to create a shade of green, however it developed a shade of brown, as though the 'Palatinate Purple' dye was actually purple in colour. When combined with 'Flame' it progressed from being a dark purple/brown colour to orange/brown indoors, then faded as the 'Flame' dye. The effect of the dark blue on the colour combination lessened as the 'Palatinate Purple' faded and the colour of the 'Flame' dye remained. When combined in the Stripe design (shown in Figure 5.15, p.94) the mixture created a shade of brown and faded from brown to blue to orange. Because of these differing results, the dyes will be mixed together in the next test so that they are in the same system before printing. Their colour and fading will then be observed.

The combinations of 'Rush Yellow' and 'Sea Green' and 'Rush Yellow' and 'Aqua Green' both develop to a shade of green, with the 'Sea Green' combination the deepest in intensity. 'Sea Green', as the slower fading dye, remains on the substrate for longer. The developed colours of 'Plum Red' and 'Claret' are similar in hue and the colours of the developed combinations of 'Corn Yellow' and 'Plum Red' and 'Corn Yellow' and 'Claret' are very similar. As the fade back speed of 'Plum Red' is faster than that of 'Claret', its effect within the colour combination is lessened sooner. Both these examples show how the dyes could be developed to the desired colour whilst using a combination that had the most effective fade rates for a chosen design.

Occasionally there was some overlap in the printing of the squares enabling the underlying colour to be visible as the pairs of dyes faded. Although this did not highlight any unusual behaviour in the colour combinations and fading patterns overall, it did appear that when the 'Cardinal' dye was printed on top of the 'Aqua Green' dye, the 'Aqua Green' acted as a mask and seemed to block the 'Cardinal' as the pair faded. The order in which these two dyes are printed may affect the colour that is seen as they fade.

'Cardinal' faded back through salmon to a shade of yellow and then dark cream when combined with the other dyes. The yellow that it contains may be why it sits amongst the yellow and orange dyes in the fading order rather than with the faster fading mauve/purple 'Plum' and 'Claret' dyes.

Overall the resulting developed colours were not surprising however dye blends can appear different on different days in different conditions due to the variation in the activation wavelengths of the dyes [5.11]. This reasonably accounts for differing shades of colour being observed, notably the colour combination and fade back of 'Flame' and 'Palatinate Purple' and highlights the inability to control the visual aspect of the dyes when they are developed by natural UV light.

Although a very subtle observation, it was also noted that as well as not developing as brightly, the dyes develop more slowly on duller, cloudier days than on sunny, cold days. Although their development was rather immediate, the combined dyes were seen to be moving through changes as they 'coloured up' in the sunlight. As the intention is

to use the dyes in an interiors setting, away from direct sunlight, the aim is to manage environmental factors so they would have a considerably lessened impact on the dyes.

Order of printing

‘Aqua  : ‘Cardinal’ 
Green’

Based on the above observations, ‘Aqua Green’ and ‘Cardinal’ dyes were re-printed in combination to see if the position of the dye within the two layers, i.e., if it was the under layer or the top layer, affected the colour created and the subsequent fading pattern. The printing and method used were as described at the start of Section 5.4.4.

Observations:

The following observations were made:

- a comparison between the resulting colour of each sample within the pair when they had developed
- a comparison between the visible colour of each sample within the pair as they faded

Results:

When ‘Aqua Green’ dye was printed on top of the ‘Cardinal’ dye the resulting colour was predominantly ‘Cardinal’. When the ‘Cardinal’ dye was printed on the ‘Aqua Green’ dye, the underlying ‘Aqua Green’ was noticeable within the print as though it had been the top layer printed, as in the previous test. The latter print also appeared slightly lighter than the first. (The prints were repeated to ensure no mistake had been made in the printing order with the same result.) As the sample of ‘Cardinal’ dye printed on ‘Aqua Green’ faded it continued to be the lightest of the pair until both samples appeared the same colour, i.e., after approximately three minutes. Thereafter the samples continued to fade at the same rate displaying the same colour.

Discussion:

It could have been expected that when the ‘Aqua Green’ dye was printed on top of the ‘Cardinal’ dye the resulting colour would predominantly be ‘Aqua Green’ and vice versa. ‘Aqua Green’ is also a fast fading dye so for it to be visible for approximately three minutes was unexpected. The ‘Cardinal’ dye has also given unexpected results in

some of the previous experiments, appearing to be the most unpredictable of the dyes. Therefore consideration will need to be given to its use in forthcoming design work.

5.4.5 *Mixing photochromic dye colours in the same system*

The Reversacol dyes used for testing were:



As the fading of the combined 'Flame' and 'Palatinate Purple' dyes differed in Sections 5.3.3 and 5.4.4, the dyes were again mixed together prior to printing to observe their fading pattern. Additional selected combinations of dyes were also mixed prior to printing to see whether their fading pattern differed when combined in this way. Dyes from opposite sides of the colour wheel and opposite ends of the fading order were chosen as this would help to highlight any differences.

The following colour combinations were used:

- 'Flame' and each of 'Aqua Green', 'Claret', 'Palatinate Purple' and 'Sea Green'
- 'Corn Yellow' and each of 'Claret' and 'Palatinate Purple'
- 'Rush Yellow' and 'Claret'

See Appendix K.

Observations:

The following observations were made:

- resulting colour when the mixed dyes had developed
- colour effects as the dyes faded

The dyes that had been mixed in the same system were then placed side by side with the corresponding samples of dyes that were mixed by printing. They were developed in sunlight, photographed as above and the following observations made:

- a comparison between the resulting developed colours
- a comparison between the colour effects of each set of dyes as they faded

Results and Discussion:

When the corresponding samples from the dyes mixed in the same system and those printed one on top of the other were placed side by side, it was apparent that the latter were all markedly deeper in colour when they had developed. However, the dyes mixed

in the same system gave a cleaner print with the resulting developed colour appearing more cohesive and defined. The fading of this set of samples was also smoother and more seamless without the appearance of such a sudden drop off in one colour.

The samples of the dyes mixed in the same system were initially the fastest to fade. After approximately six minutes, the samples from each pair (of dyes mixed in the same system and those printed one on top of the other) appeared to have faded back to the same colour and continued to fade at the same rate thereafter.

When 'Flame' and 'Palatinate Purple' dyes were mixed in the same system, the dyes were initially a blue/grey colour that then faded to brown and then to orange. This was different again from the results in Sections 5.3.3 and 5.4.4. All of the printed squares from this set of tests were moved from indoors to outdoors and then indoors again so that they could be observed as they developed in varying levels of UV light. The colours of the combinations varied as the UV light levels varied. They were also observed on different days so the atmospheric conditions were different. The combination of 'Flame' and 'Palatinate Purple' dyes, both bright in colour, from opposite ends of the colour spectrum and opposite ends of the fading order, that has shown variations in the shades of developed colour and fading patterns, is a good example of atmospheric conditions affecting the dyes. Additionally, the change that 'Palatinate Purple' moves through, from pale green to light blue to dark blue, when developing, or inversely when fading, and the intensity of colour that it shows at each stage, dependent on how much it is affected by atmospheric conditions, would have an impact on the colour that is seen when it is used in combination. This was also clearly observed in Section 5.4.4 when 'Palatinate Purple' was mixed with 'Corn Yellow'.

The placement of the dyes (used in a design that cleverly utilised and reinforced their changing colours) in a space where natural UV light levels regularly fluctuated would be a means of embracing their unique qualities. An indepth study of the fading patterns and the subsequent colours that the dyes appear in varying conditions would assist in creating appropriate designs needed to do this. This is another area for consideration in future work.

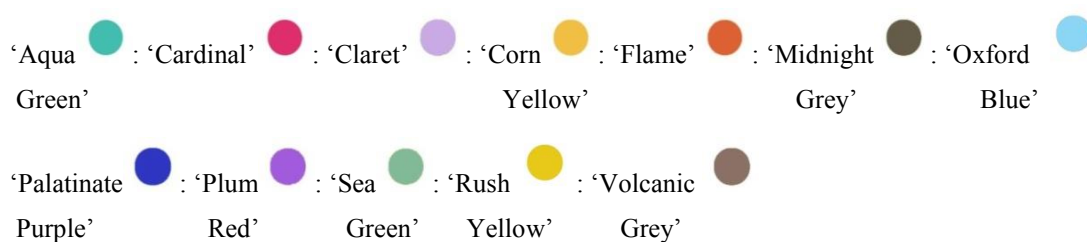
By looking at the photographs of the dyes that had been mixed in the same system as they progressively faded, it could be seen that after approximately 45-50 seconds the

definite distinctiveness of colour between each printed square had decreased. After one and a half minutes of fading there had been a further noticeable drop off in colour. This occurred again at approximately four and then six minutes with the dyes continuing to fade thereafter. They were observed for just over 10 minutes. Although the times stated are approximate, it demonstrates very clearly that as the dyes progressively fade there are differing levels in the depth of colour visible on the substrate at various stages, and this continues until there is little or no colour visible. This was initially highlighted in Section 5.4.3 and is important to note when considering how developing dyes would appear on the substrate, as they are used to create changing imagery/motifs, in conjunction with dyes that are fading. Clearly there is a difference between the brightness of dyes that have just developed, and those that have faded considerably, such as the shades of pale yellow or peach that the slower fading dyes of ‘Flame’, ‘Corn Yellow’ and ‘Cardinal’ leave on the substrate. However, there is less of a difference in intensity of colour between those dyes that have just developed and those that have been fading in the background for a shorter period of time. Therefore, co-ordination of the dyes so that their colour and movement interactions are both constructive and effective, will be needed as they are used to create a moving image.

5.5 Evaluating Surface Qualities and Finishing Techniques

5.5.1 *Dyes printed on sateen*

The Reversacol dyes used for testing were:



Based on the results of initial tests showing the strength of colour of the dyes on a variety of substrates (Section 5.3.2), cotton drill was selected as the fabric substrate for use, at this stage, for the project. In reference to the screen qualities of French Impressionist films, it was decided to print the dyes on cotton sateen, a fabric that is smooth to touch and has a noticeable sheen to its surface. As the texture of the substrate affects the developed colour of photochromic dyes (Sections 5.3.1 and 5.3.2) they were printed on both cotton drill and sateen and compared. See Appendix L.

Observations:

The following observations of the printed dyes were made when they were exposed to natural UV light:

- intensity of colour
- texture of both substrates

Results:

There was minimal difference in the appearance of the strength of colour of the dyes on both the drill and sateen samples, with the results consistent across the colour range. Although the texture of printed sateen appeared smooth and sleek, the surface sheen that was noticeable on the unprinted fabric was not apparent after it had been printed with the dyes.

Discussion:

The woven texture of the cotton drill fabric gave more of a ‘textile’ and subtle tactile appearance to the substrate. As the aim is to achieve narrative using these dyes on a textile substrate, not necessarily to replicate films on fabric, cotton drill remained the preferred choice of substrate at this stage.

5.5.2 *Devoré technique*

The Reversacol dye used for testing was:

‘Cardinal’ 

As illustrated in Section 5.4.3 (Figs. 5.38 and 5.40), the dyes have the potential to create the appearance of depth within imagery. Printing these dyes onto a substrate that already has a three-dimensional surface, one that is already in relief created by devoré paste [5.12], may be useful for providing a further element of depth to the visual effects created by the dyes. ‘Cardinal’ dye was chosen because it provided a bright contrasting colour against the background of the cream silk/viscose fabric. See Appendix M.

Observations:

The following observations of the printed dye were made when it was exposed to natural UV light:

- intensity of colour
- appearance of the design during and after development of the dye

- consistency of the print of the dye on the fabric

Results and Discussion:

As the devoré process may have removed the photochromic dye, or diminished its effect, it was carried out first. The process caused the fabric to shrink making the printed design larger than the burnt out area. Although applying the devoré process after printing the photochromic dye would enable the dye and the burnt out area to match up, the 3D effect may not be as effective. An alternative to the chemical process would be to use laser cutting to experiment with creating various depths of relief within the substrate. The effect of heat, from the laser cutting process, on the photochromic dyes would need to be observed. Another alternative would be to calculate the percentage of shrinkage of the substrate that would occur during the devoré process, so that this could be compensated for in the design process, i.e., it could be planned that the burnt out area would match up with the printed area. Although they would be interesting areas to investigate, neither of these effects will be explored further in this project.

Although the dye was printed on the back of the fabric (as this was a flatter and more even surface than that created by the pile on the front of the fabric) the developed ‘Cardinal’ dye was bright and very clearly visible on the front, allowing the 3D effect to be clearly seen. When the dye developed it appeared to emerge from the fabric and spill over, filling in part of the burnt out area that had been made by the devoré process (Fig. 5.71). This created a sense of movement and shadow, particularly because the dye was placed a little away from the burnt out area. The depth of approximately 1mm of the burnt out area enhanced this effect. The dye colour appeared darker in the ‘wall’ of the burnt out areas.




Fig. 5.71 Developed ‘Cardinal’ dye on devoré silk/viscose velvet

Experimentation with dye colour and strength, placement, and development and fading coordination, matching/mismatching the print and the burnt out area and using either the devoré or the laser cutting processes may enhance the visual effects created by these dyes. Although these effects won't be explored further in this project, they would be interesting to explore in future work.

5.5.3 *Dye printed on pre-felt*

The Reversacol dye used for testing was:

'Flame' 

Felted wool, due to its different thicknesses and pliability, would provide an appropriate substrate within which to insert tiny Light Emitting Diodes (LEDs) for the purpose of developing the dyes. The risk of burning with this light source would be minimal and wool has the benefit of low flammability. Although the dyes developed more brightly on cotton, and the colour of the developed dye on wool differed from its appearance on the other tested substrates, as shown in Section 5.3.2, the texture of the felt may reflect the sometimes blurred and hazy appearance of the screen image in the French Impressionist films, emphasising the textile aspect of the substrate. 'Flame' dye was chosen because it provided a bright contrasting colour against the cream colour of the wool. See Appendix N.

Observations:

An assessment of the suitability of felted lambswool was made based on the following criteria:

- colour of developed dye
- consistency of the printed dye over the substrate
- thickness of the felted lambswool
- pliability of the lambswool

Results and Discussion:

The wool pre-felt was printed before hand-felting to decrease the finishing processes with the intention of minimising the loss of softness and thickness. However, the resulting surface texture was inconsistent and would affect the definition of any printed image (Fig. 5.72).



Fig. 5.72 Developed 'Flame' dye printed on felt

The colour of the developed dye on felt was comparable with when the dye was printed on cotton.

Before felting, the lambswool was very soft. After the printing and finishing techniques had been applied it was thinner, more condensed and firmer, as expected, because the fibres had been compacted by the felting process, however it was still soft and very pliable. After being kept in a sketch book the felt flattened creating a smoother surface texture whilst still giving the developed dye a hazy appearance on the substrate. This showed the potential that felt has as a substrate for this project, although further sampling would be necessary to refine its use from a printing and design perspective. The effect created by UV light from LEDs, as they developed dyes printed on this substrate, would also need to be explored. Additional research of both of these components would be useful, however neither will be explored further within this project.

5.6 Extrusion of Photochromic Dyes in Polypropylene

Photochromic dyes are very system or matrix dependent, the matrix being the medium to which the dyes are added in order to achieve a photochromic response. This might be a solvent, resin, plastic or coating. The system or matrix can affect the speed, colour and fatigue properties of the dyes [5.13]. To extrude means to squeeze or force out, to produce (moulded sections of plastic, metal, etc) by ejection under pressure through a suitably shaped nozzle or die [5.14]. Mixing photochromic dye powder with polypropylene pellets and putting them through the process of extrusion can effectively produce a monofilament that will develop from colourless to coloured when exposed to

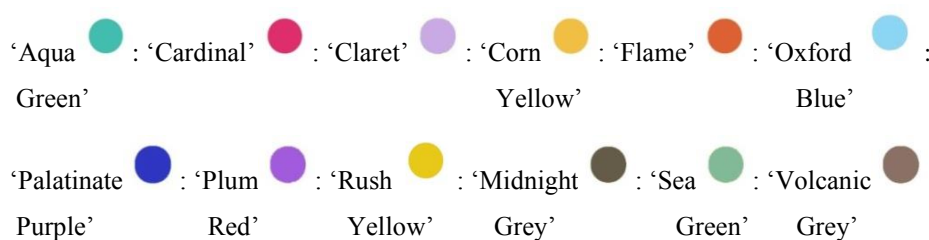
UV light. The colour of developed extruded photochromic dyes is of a markedly stronger intensity than that of developed printed photochromic dyes. Using a combination of both, as mixed media, would provide more options within design development from both a colour and a surface design perspective.

5.6.1 Extrusion of dyes using Ram extruder

The process of learning to extrude polypropylene was carried out using established settings [5.15]. Once this skill was gained, settings were refined to create a monofilament of a thickness equivalent to that of a fine yarn. These are written below. As these were preliminary tests, the yarn count and physical properties were not measured. See Appendix O.

5.6.2 Fading of extruded dyes

The Reversacol dyes used for extrusion were:



The dyes were extruded following the method as described in Section 5.6.1 and observed to gain an understanding of their characteristics when they are in this system and developed by natural UV light. Their response to artificial UV light will be measured more precisely in future experiments. See Appendix P.

Observations:

The following observations were made:

- actual hue
- intensity of colour
- fading order
- general fading times

Results:

Before developing, the monofilament containing the photochromic dyes was clear. When taken out into sunlight the colours of the dyes immediately began to develop.

Some of the extruded dyes developed into a completely different colour from the printed dyes, as shown in Table 5.11 and Figure 5.78. ‘Oxford Blue’ became a shade of lilac, ‘Palatinate Purple’ a deep purple and ‘Cardinal’ became orange/pink in colour. The variations in the grey dyes are more accentuated when extruded than when printed, with ‘Midnight Grey’ containing a definite red tone and ‘Volcanic Grey’ appearing a mauve/grey in colour.

Dye	Actual colour	Fading order	Intensity of colour
‘Rush Yellow’	light yellow	1	1
‘Oxford Blue’	lilac	2	2
‘Plum Red’	deep pink	3	9
‘Corn Yellow’	gold/yellow	4	3
‘Claret’	hot pink	5	8
‘Flame’	orange	6	7
‘Midnight Grey’	grey with red tone	7	4
‘Cardinal’	orange/pink	8	6
‘Palatinate Purple’	dark purple	9	12
‘Volcanic Grey’	mauve grey	10	5
‘Aqua Green’	deep green	11	10
‘Sea Green’	deep sea green	12	11

Table 5.11 Intensity of colour and fading order

Table key

1 = exhibits least of this property (in this case the palest or the fastest)

12 = exhibits most of this property (in this case the brightest or the slowest)



Fig. 5.73 Extruded dyes arranged in their fading order, see Table 5.11, and developed in sunlight for one minute.

Back row: ‘Sea Green’, ‘Volcanic Grey’, ‘Cardinal’, ‘Flame’, ‘Corn Yellow’, ‘Oxford Blue’

Front row: ‘Aqua Green’, ‘Palatinate Purple’, ‘Midnight Grey’, ‘Claret’, ‘Plum Red’, ‘Rush Yellow’



Fig. 5.74 Extruded dyes fading indoors after two minutes 15 seconds



Fig. 5.75 Extruded dyes fading indoors after nearly ten minutes

Figure 5.73 clearly shows the strength of colour of the dyes in this form. Those that developed to the strongest intensity ('Sea Green', 'Aqua Green' and 'Palatinate Purple') appeared to 'colour up' in response to sunlight more immediately than the remainder of the dyes, and were also the slowest to fade, see Table 5.11.

When the dyes were observed for a second time, the initial fading order noted was re-confirmed. When removed from sunlight, the draining of colour from the 'Rush Yellow' and 'Oxford Blue' monofilament was almost immediate, i.e., within 15 seconds. Figure 5.74 shows how much colour has faded after just over two minutes. 'Volcanic Grey' did not develop as intensely as 'Palatinate Purple' and initially appeared to lose colour more quickly than this dye, however they swapped fading order after nearly 7 minutes with 'Volcanic Grey' then being the slower of the two to fade. The majority of the dyes had lost most of their colour after nearly 10 minutes (Fig. 5.75), and subsequent fading continued slowly. The under layers on the yarn cones did not develop as intensely as the outer layers. Even though it looked as though there was some colour remaining in the fibre, when viewed in isolation it was only very lightly coloured or clear. After 22 minutes, 'Sea Green' was still a deep green in colour.

Comparing Tables 5.10 and 5.11, it can be seen that the fading order of the extruded dyes, differed markedly from that of the printed dyes. They also did not fade according to colour groups in the same way as the printed dyes. 'Aqua Green' and 'Palatinate Purple', as faster fading dyes when printed, were much slower fading when in extruded form. 'Sea Green' moved from the middle of the fading order of the printed dyes to being the slowest fading extruded dye. 'Rush Yellow', 'Corn Yellow' and 'Flame', as slower fading dyes when printed, were much faster fading when extruded.

Discussion:

The fade rates of the printed dyes, as a group, are noticeably faster than those of the extruded dyes. According to the manufacturers, the dye fade rate is faster (by up to

50%) in solvent systems as the dye is unhindered in the structural change to return to the uncoloured form [5.16].

Although coloured when developed, the extruded fibre is initially transparent, so the way in which it is used - its thickness when extruded, whether a monofilament or a multifilament, or combined with the printed dyes (the combination of the two forms determining the resulting colour) - would affect the strength of colour and therefore its visual impact.

Using both printed and extruded dyes in mixed media designs would provide a larger colour palette from which to draw. The differences in the individual fading times of the printed and extruded dyes as well as the differences in fading times between the two systems would also provide more options and widen the parameters for developing designs.

5.7 Developing Photochromic Dyes with Artificial Light

As the aim was to use artificial UV light to control the dyes, their colour development was initially observed under UV light tubes. After encouraging results, the dyes, both printed and extruded, were developed by UV LEDs. Their response, to a range of currents over different time frames, was measured. The subsequent results, as well as the marks made on the substrate as the dyes developed, illustrated that the LEDs would provide UV light in a suitable form for exploring the project aim.

As the conceptual setting for the resulting design product would be indoors, where fluorescent light is present, the dyes' response to this form of light was also observed.

5.7.1 Developing dyes with 365nm light tubes

Although the dyes are preferably developed with light from the 350-410nm range [5.17] with the optimum wavelength being around 365nm [5.18], the printed photochromic dyes were placed under 254nm, 302nm and 365nm light tubes. During initial observations, all of the dyes developed colour under each of these wavelengths. Although some activation of the dyes may occur at approximately 340nm [5.19], it has been reported that light tubes may contain light from a wider spectrum than that for which they are categorised, which would explain why the colours of the dyes were developed by the 254nm and the 302nm tubes. As the dyes develop optimally under

365nm, it was decided to observe their development under this wavelength only. See Appendix Q.

Observations:

The following observations of the printed dyes were made:

- actual hue
- intensity of colour

Results and Discussion:

Dye	Colour
‘Oxford Blue’	pale blue
‘Plum Red’	mauve/lilac
‘Aqua Green’	blue/green
‘Claret’	bright mauve
‘Palatinate Purple’	blue
‘Sea Green’	blue/green
‘Rush Yellow’	strong yellow
‘Volcanic Grey’	grey
‘Midnight Grey’	grey
‘Cardinal’	rich, dark pink
‘Corn Yellow’	strong yellow/gold/orange
‘Flame’	orange/rust

Table 5.12 Dyes developed under 365nm UV light tubes

Table 5.12 shows the colours of the dyes when they were developed by the 365nm UV light tubes. It was noticeable that the intensity of their developed colour was less than when they were developed by natural UV light. However, it was also of a sufficient depth to illustrate that continuing to explore artificial UV light, as a means for developing the dyes, was worthwhile.

As in Sections 5.3.5 and 5.3.6, the ‘Cardinal’ dye stained the substrate a pale yellow after it had been developed by the UV light tubes. This will need to be considered in future observations and design work.

5.7.2 Developing photochromic dyes with light emitting diodes

To accomplish the project aim of achieving visual narration on a textile substrate, an appropriate form of artificial UV light with which to develop the dyes needed to be identified.

A photochromic dye is not developed by only a specific wavelength of UV light, i.e., one wavelength of light does not 'pick out' and develop only a specific colour. For example, 370nm of UV light does not develop only a particular dye that develops into the colour green, just as 390nm of UV light does not develop only a particular dye that develops into the colour blue [5.20], with no other colour nearby being developed. The surrounding dyes and their subsequent colours would also develop. Although the green dye may develop to its peak, i.e., giving its brightest colour, at 370nm and the blue dye its brightest colour at 390nm, the green dye would also develop at 390nm and the blue dye at 370nm, although each not developing quite as brightly as at their own peak range [5.21]. Therefore, shining a particular wavelength of UV light onto a substrate, like a theatre curtain backdrop, that had been printed with a design consisting of various colours, would potentially develop most or all of the dyes, some brighter than others, at the same time. Certainly the size and angle of the light beam would affect the area that the light covered and the subsequent amount that the dyes developed. Once the UV light stopped shining on the curtain the whole image would fade, some colours more quickly than others. Consequently, rather than having colours appearing and then disappearing in selected areas, the motifs of the image would develop and become visible at much the same time. When the light source was removed, the colours would fade in a staggered order.

The dyes are preferably activated with ultraviolet light from 350nm-410nm [5.22]. Research found lasers able to emit beams of UV light from 365nm-400nm however the cost of approximately £50000 made their purchase prohibitive [5.23]. Although the outcomes of this design project may ultimately be applied to other applications, an excessively high price tag would severely restrict the main commercial audience to which it is directed. Apart from the difficulty in isolating the development of the individual colours of the dyes by this means, a laser UV light source used within this scenario could potentially be very dangerous. A light source that was safe to use whilst also giving the user a degree of governance over the dyes, with only those selected developing upon demand, was needed. Controlling the projection of UV light upon the substrate would also enable the capabilities of the dyes to be explored and subsequently utilised.

5.7.2.1 Light emitting diodes

An LED is a semiconducting device that converts electricity into light [5.24]. Like a tiny light bulb, the LED is widely used to create illuminated displays such as those used

as message and destination boards at airports and railway stations, and in electronic devices [5.25] [5.26]. They can also be used to emit UV light. When considered for use within this design application, the following advantages of LEDs were noted [5.27]:

- easily configured onto circuit boards
- light up very quickly
- the solid package of the LED can be designed to focus its light
- ideal for use in applications that are subject to frequent on-off cycling
- LEDs mostly fail by dimming over time, rather than the abrupt burn-out of incandescent bulbs
- they radiate very little heat that could cause damage to sensitive objects or fabrics, and wasted energy is dispersed as heat through the base of the LED. As heat is counter to the development of photochromic dyes this potential problem would also be minimised.
- LEDs are difficult to damage with external shock

As previously mentioned, photochromic dyes/colours are highly system dependent with the substrate and system in which the dyes are used affecting their photochromic response [5.28] [5.29]. The dyes have a 'none' to 'excellent' response to 410nm LEDs and a 'good' to 'excellent' colour response to 380nm LEDs, when tested at 0.05% w/w in low density polyethylene [5.30] at 23°C (this is one of the standard temperatures used for tests within the ophthalmic industry [5.31]). As shown in previous sections, the dyes develop brightly when printed on cotton drill and extruded in polypropylene and developed by natural UV light. The colour and fade responses of the dyes in both these systems when exposed to UV LEDs had not previously been explored or measured. Therefore, the responses of the dyes when developed by this form of light source needed to be ascertained.

UV LEDs emitting a range of wavelengths, from 255-400nm, were available from both China and the USA. However, the cost of the LEDs from either of these sources was very expensive, and with minimum quantities for purchase required. The time frame for delivery (4-6 weeks) was also a consideration. 400nm and 370nm LEDs were both available from a UK supplier [5.32]. When thinking of the larger design scenario, the cost, safety factors and availability of the LEDs were considered. As the dyes respond differently in different systems, and each reach their peak at different wavelengths of UV light [5.33], it was decided to initially observe their development and fading

responses, and visual presence, when developed by LEDs emitting 400nm of UV light. The dyes would then be observed when they were developed by 370nm LEDs. A decision about whether LEDs would be appropriate for creating a design platform, and then subsequently the wavelength of LEDs to use, could then be made.

5.7.2.2 Measurement of printed photochromic dyes developed by 400nm LEDs

The Reversacol dyes used for testing were:



To achieve the aim of visual narration the dyes need to be visible on the substrate for different periods of time to contribute to the creation of imagery/motifs that would change in sequence.

When the dyes were developed by sunlight and then removed from that light source, they initially faded quickly losing the impact of their colour within the first 30 seconds. This was followed by a slower fade of the remaining colour. Developing the dyes with artificial UV light over a range of exposure times and currents would determine whether the amount of time they were exposed to, and the strength of current applied by, that light source, would affect the colours developed and subsequent fade rates.

As the dyes have been observed developing quickly upon exposure to natural UV light and as the moving images within films change quickly, the times of 2, 5 and 10 seconds were chosen to develop the dyes in this set of observations. It would also enable their potential to create rhythmic movement, as discussed in Section 3.3.3, to be explored.

A 400nm LED, with a 5mm lamp size and a round lens shape [5.34], was used to develop the printed photochromic dyes at a range of currents and exposure times to observe their appearance and fade times. See Appendix R.

Observations:

The following observations of the printed dyes were made with a second observer, Ashleigh Barron, when they were exposed to the UV LED:

- actual hue
- intensity of colour
- spread and bleeding
- fade time

Results:

Figures 5.76-5.78 and Table 5.13 show the results of the observations of the printed photochromic dyes when exposed to a range of currents. Results for the fade rates of individual dyes can be seen in Appendix R.1.

Comparison of Figures 5.76-5.78:

On each graph, the X axis shows the currents used (in milliamps): 1, 2, 5, 10, 15, 20, 30, 50, 70 and 100mA. The Y axis shows the fade times (in seconds).

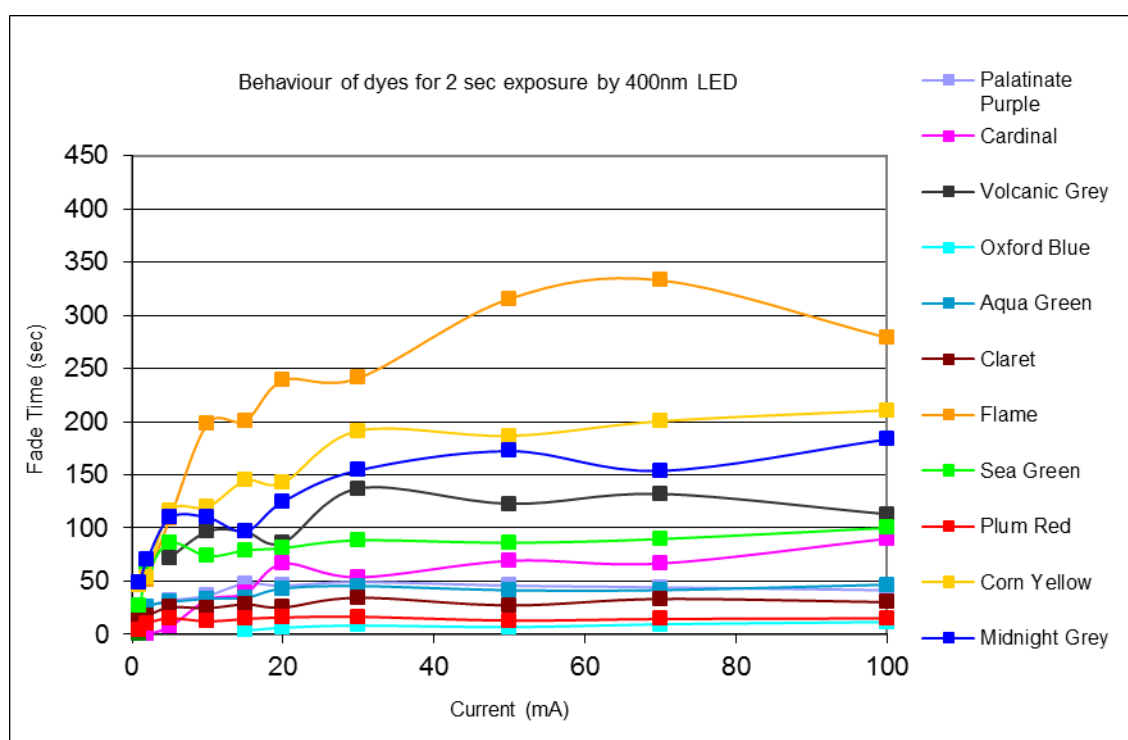


Fig. 5.76 Results of photochromic dyes printed on cotton drill developed by 400nm LED for 2 seconds

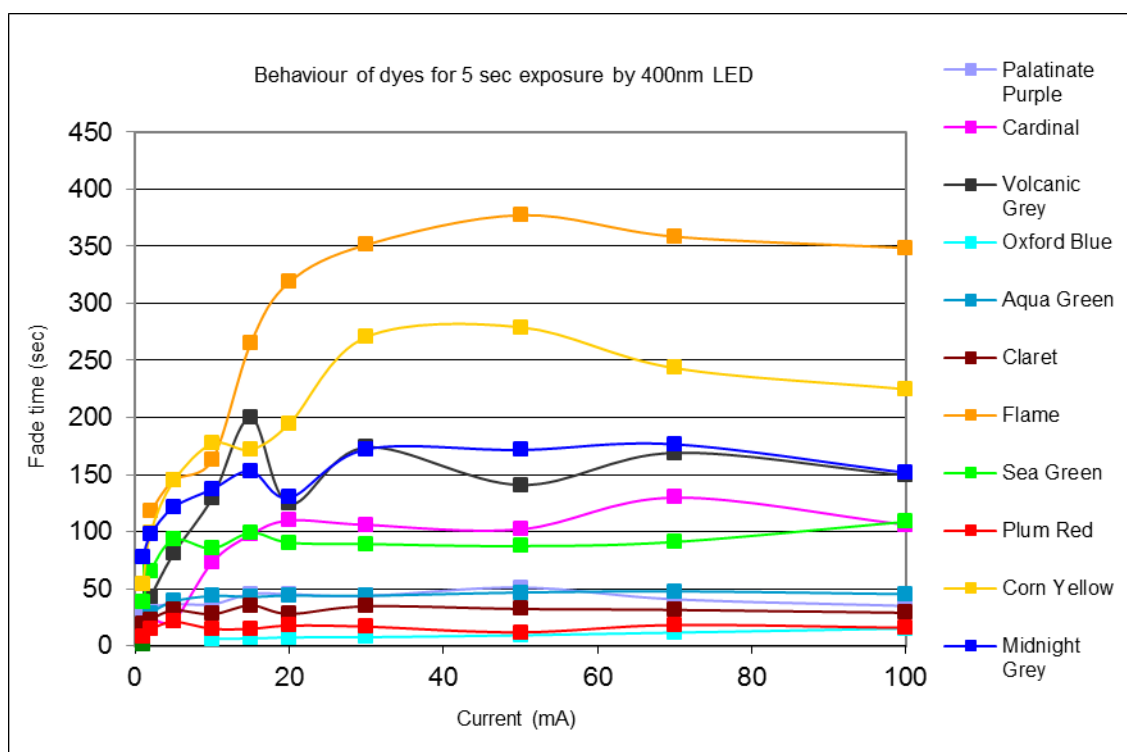


Fig. 5.77 Results of photochromic dyes printed on cotton drill developed by 400nm LED for 5 seconds

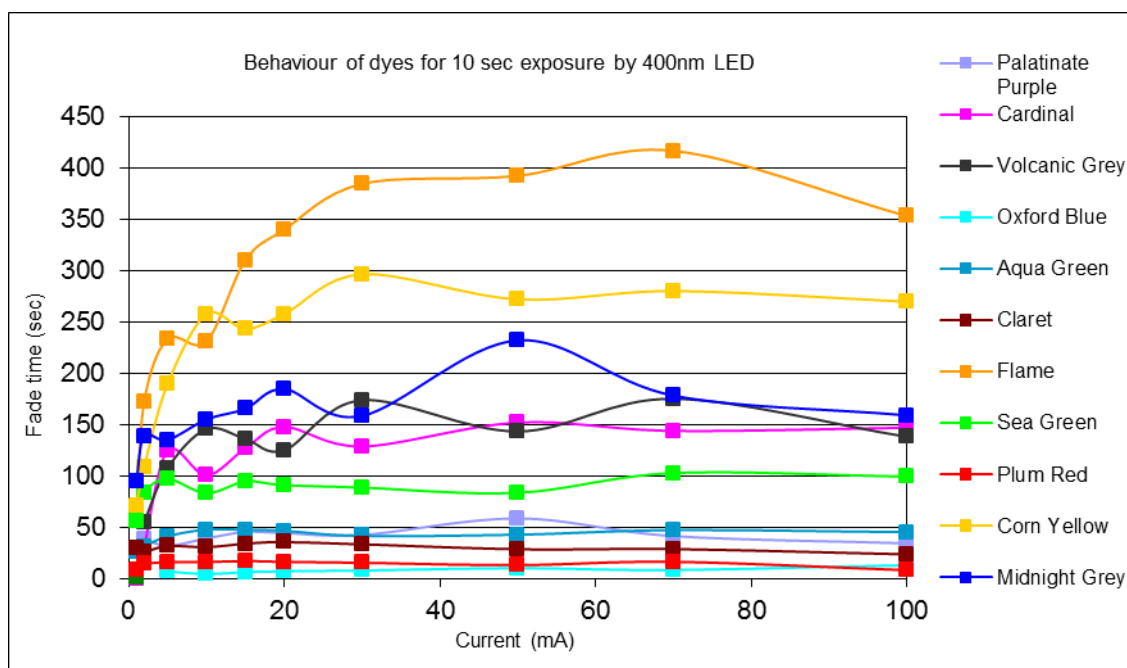


Fig. 5.78 Results of photochromic dyes printed on cotton drill developed by 400nm LED for 10 seconds

Figures 5.76, 5.77 and 5.78 show the exposure times for each dye at 2, 5 and 10 seconds respectively. As can be seen in each graph, from 1mA to 2mA there was a dramatic increase in the fade times. Before 20mA, the fade times are more variable and less reliable. At 20mA, the behaviour of the dyes levelled out with their fade times appearing to spread out and find their position in relation to one another, remaining generally consistent thereafter. The dyes showed the same trend in their order of fading

at 20mA when exposed to each of the time intervals of 2, 5 and 10 seconds, see Table 5.13. These results are relevant and can be applied to design work as they reflect how the dyes would behave when fading in a design. ‘Volcanic Grey’ and ‘Flame’ did not develop at the 1mA and/or 2mA currents and ‘Oxford Blue’ did not develop consistently until exposed to the 15mA current.

Dye	2 second exposure	5 second exposure	10 second exposure
‘Oxford Blue’	1	1	1
‘Plum Red’	2	2	2
‘Claret’	3	3	3
‘Aqua Green’	4	4	5
‘Palatinate Purple’	5	5	4
‘Cardinal’	6	7	8
‘Sea Green’	7	6	6
‘Volcanic Grey’	8	8	7
‘Midnight Grey’	9	9	9
‘Corn Yellow’	10	10	10
‘Flame’	11	11	11

Table 5.13 Fading order of each of the dyes developed by 400nm LED at 20mA for each of 2, 5 and 10 seconds exposure

Table key

1= exhibits least of this property (in this case fastest to fade)

11 = exhibits most of this property (in this case slowest to fade)

Experimental errors:

Target exposure time	Actual exposure range	Average exposure	Standard deviation
2	2.02 – 3.87	2.5	0.24
5	4.09 – 5.85	5.4	0.22
10	9.99 – 10.98	10.4	0.17

Table 5.14 Target and actual exposure times in seconds

The aim was for the dyes to be exposed to the light source for 2, 5 and 10 seconds, however, because the stop watch was manually controlled there were variations in the exposure times, see Table 5.14. Experimental errors were also measured, and are displayed, for each of the subsequent tests in Sections 5.7.2.3-5.7.2.9.

When developed at 20mA the following anomalies occurred. At 2 seconds exposure ‘Palatinate Purple’ and ‘Cardinal’ cross over. At 5 seconds exposure ‘Corn Yellow’, ‘Midnight Grey’ and ‘Volcanic Grey’ cross over, and ‘Cardinal’ and ‘Sea Green’ cross

over. At 10 seconds exposure 'Volcanic Grey' and 'Cardinal' cross over, see Figures 5.76-5.78. Where the lines are close together and cross over, experimental errors may cause the differences. Small variations in the time of exposure may have influenced the fade times. The differences shown may not be significant. They may be explained by the subjectivity of the observations. Thus, repeat experiments were made at 20mA for 5 seconds.

5.7.2.3 Repeat experiments made at 20mA for 5 seconds

The process described in Section 5.7.2.2 was repeated three times at 20mA for five seconds to establish consistency of results. In practice, the 5 second exposure ranged from 5.02-5.42 seconds with an average exposure time of 5.24 seconds and a standard deviation of 0.1.

The purpose of repeatability is to show the certainty of the dyes remaining visible on the fabric at the same time. Margins can then be established from which to choose the dyes to be used. For example, dependent on the desired effect, two dyes could be chosen that were further apart in their fade times, such as 'Palatinate Purple' and 'Flame', or alternatively three colours may be chosen that would remain on the fabric for a similar amount of time, such as 'Midnight Grey', 'Cardinal' and 'Corn Yellow', or part thereof, such as 'Plum Red', 'Sea Green' and 'Volcanic Grey' in a more obvious staggered effect, see Figure 5.79.

Results and Discussion:

Figure 5.79 shows the results of the repeat experiments. Results for the fade rates of individual dyes can be seen in See Appendix R.2.

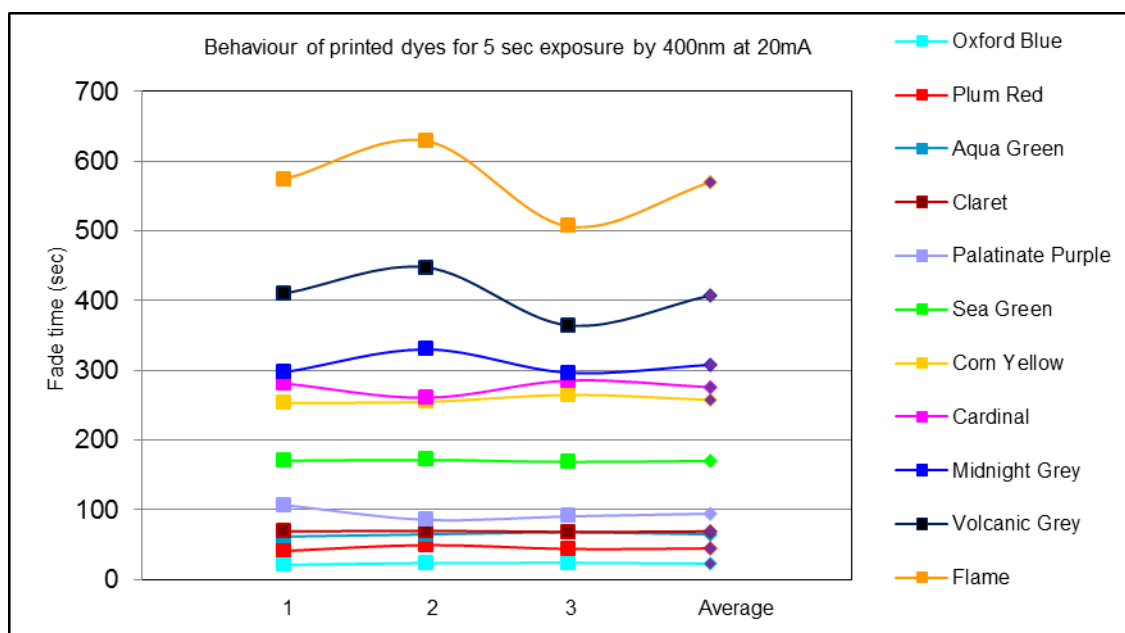


Fig. 5.79 Repeat experiments of printed dyes with 400nm LED at 20mA current for 5 seconds. The purple diamond at the end of each row marks the average fade time for the dyes.

The fading times of the dyes in the repeat experiments were consistently slower, taking approximately twice the time of the earlier experiments. In the first set of experiments measurements were taken when the colour was no longer readily apparent. As these were repeat experiments, measurements were taken when the colour was deemed to be exactly the same as the background colour. Except for ‘Corn Yellow’, the trends were very similar with the faster fading dyes continuing to be at the top of the list, the slower fading dyes at the bottom of the list, and the ranking in much the same order as in the previous set of experiments, see Tables 5.13 and 5.15. ‘Corn Yellow’ moved from being the second slowest dye to fade to being in the middle of the fading order.

Dye	5 second exposure
‘Oxford Blue’	1
‘Plum Red’	2
‘Aqua Green’	3
‘Claret’	4
‘Palatinate Purple’	5
‘Sea Green’	6
‘Corn Yellow’	7
‘Cardinal’	8
‘Midnight Grey’	9
‘Volcanic Grey’	10
‘Flame’	11

Table 5.15 Average of fading of printed dyes at 20mA for 5 second exposure

Table key

1= exhibits least of this property (in this case fastest to fade)

11 = exhibits most of this property (in this case slowest to fade)

LEDs are traditionally used in displays where the need for consistency of illuminated strength is required. However, UV LEDs are used individually for security purposes and microbial cleaning [5.35] therefore their consistency of strength may not be very reliable and this may also account for the slight variation in results.

When compared with the dyes developed by natural UV light (see Table 5.10, p.116) the order of the faster fading dyes was consistent whilst there was some change in the order of the slower fading dyes. 'Corn Yellow' was also the second slowest dye to fade when observed in sunlight.

A process has now been established to test how the dyes respond to UV LEDs. This process can also be used to determine the fade rates of the dyes within other systems.

Banks' scale:

The following scale sets out the fade profile of the dyes (Fig. 5.80). This is an easy format for displaying visually at which end of the fade spectrum the dyes sit and their time of fading.

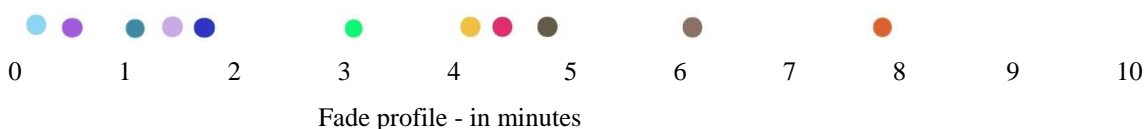


Fig. 5.80 Printed dyes - 400nm – repeated at 20mA - 5 second exposure

Banks' scale key

A horizontal scale from 0 to 10 minutes showing the fade profile of various dyes. The dots are as follows: at 0.5 minutes (light blue, purple), at 1.5 minutes (teal, light purple, dark blue), at 3.5 minutes (green), at 4.5 minutes (yellow, pink, dark grey), at 6.5 minutes (brown), and at 8.5 minutes (orange).

'Aqua Green' 'Cardinal' 'Claret' 'Corn Yellow' 'Flame' 'Midnight Grey' 'Oxford Blue' 'Palatinate Purple' 'Plum Red' 'Sea Green' 'Volcanic Grey'

Dye family fading trends:

There are two main dye families to which the photochromic dyes belong, Spiro-naphthoxazines and Naphthopyrans [5.36]. On closer analysis of the printed dyes in Figure 5.81, it can be seen that, as set out in Table 5.16, the dyes belonging to the family

Dye	Colour	Fading order	Dye family
'Oxford Blue'	light blue	1	Spiro-naphthox-azine
'Plum Red'	mauve	2	Spiro-naphthox-azine
'Aqua Green'	green	3	Spiro-naphthox-azine
'Claret'	mauve	4	Spiro-naphthox-azine
'Palatinate Purple'	blue	5	Spiro-naphthox-azine
'Sea Green'	green	6	Spiro-naphthox-azine
'Corn Yellow'	yellow	7	Naphtho-pyrans
'Cardinal'	pink	8	Naphtho-pyrans
'Midnight Grey'	grey	9	Naphtho-pyrans
'Volcanic Grey'	grey	10	Naphtho-pyrans
'Flame'	orange	11	Naphtho-pyrans

Table 5.16 Clusters of fade groups of dyes

Table key

1= exhibits least of this property (in this case fastest to fade)

11 = exhibits most of this property (in this case slowest to fade)

of Spiro-naphthoxazines, that are in the mauve/blue/green colour range, are faster fading dyes and those belonging to the family of Naphthopyrans, in the orange/yellow/red or grey colour range, are slower fading dyes. This information would be useful to a designer wanting to print with the dyes who is only aware of the colour of the dye and/or the name of the family to which a particular dye belongs.

Colours and marks made:

When the dyes were developed by the UV LEDs at each of the currents and time intervals, they were observed for the colours and the marks that they made on the substrate. They were also photographed immediately the light source was turned off. Although the photographs do not give a true representation of the colour and spread pattern of the dye as it is seen with the naked eye, they serve well as a visual reference. All photographs are set out in the accompanying sketch books.

Although the colours of the dyes appeared to develop at slightly different speeds when in natural UV light, when developed by the LED, which was placed closely below the substrate, the colours of the dyes developed immediately.

When developed by the UV LEDs the dyes give a small, concentrated and dramatic effect (Fig. 5.81). The strength of colour of the dyes when developed by this form of light source was markedly more intense than when they were developed by the 365nm light tubes in Section 5.7.1. Apart from being in a different form, there was a 12cm

distance between the light tubes and the substrate, compared with the 2-3 mm distance in these observations.

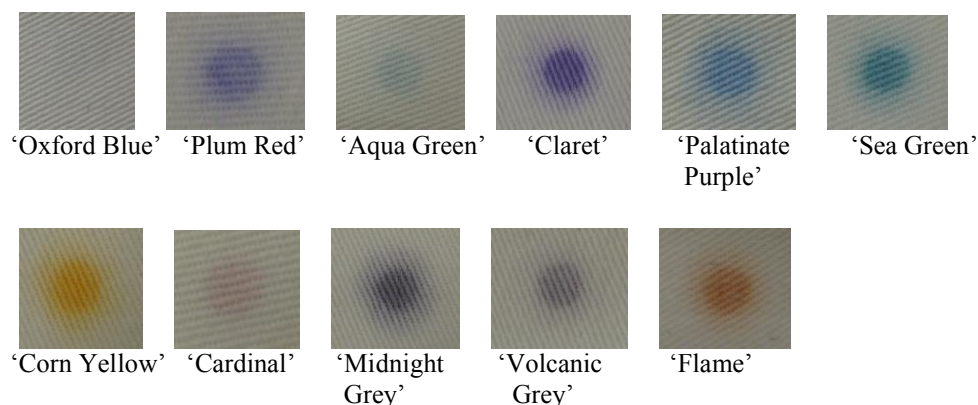


Fig. 5.81 Printed photochromic dyes developed by 400nm LED at a current of 20mA for 5 seconds

The palest and fastest fading dye, 'Oxford Blue', was barely visible at 400nm. The scant colour that could be seen faded quickly. 'Aqua Green' also appeared lightly on the substrate until developed by 20mA-30mA currents.

The hue of most of the dyes remained the same whilst deepening in intensity as the current increased, with the exception of 'Palatinate Purple' and 'Cardinal'. When developed by a current of 1mA 'Palatinate Purple' developed as a shade of blue, becoming progressively darker as the current increased until it was navy in colour at 10mA. At 15mA an inkier blue colour developed and a slightly green halo was observed, that became very definite at 20mA. However, this green colour (also previously observed as the dye faded under natural UV light) was not visible as the dye faded after being developed by the single LED. At 1mA 'Cardinal' developed as a faint yellow mark that became pale pink/orange in colour at 2mA. At 10mA the orange colour deepened, becoming progressively muddier at 20mA.

Overall, if the exposure time was higher this led to greater intensity of colour and most often to a slower fade rate, therefore as exposure times varied so did colour intensity, as illustrated in Figure 5.82. As the current increased, the colour of the dyes intensified, the surface area over which the dyes developed increased, and their mark on the substrate changed. However, as shown in Figures 5.76-5.78, the progressive increases in current did not result in an incremental increase in fade times.

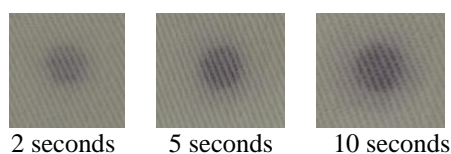


Fig. 5.82 Printed 'Volcanic Grey' dye developed by 400nm LED at a current of 20mA at each of 2, 5 and 10 seconds

Although the dyes became progressively darker in colour as the current intensity increased, there was a trend for the colour to be stronger when developed at a lower current for a longer period of time than at a higher current for a shorter period of time. For example, the colour of many of the dyes appeared stronger when developed at 15mA for 10 seconds than 20mA for 2 seconds.

It was also noted that at the higher currents the fade back time was often faster when the dyes were developed for a longer period of time. As heat increases the fade back reaction of the dyes, the increased current intensity may generate more heat. This reasonably explains why the colour may be stronger when the dyes are developed at a lower current, and why the progressive increases in current did not result in an incremental increase in fade times.

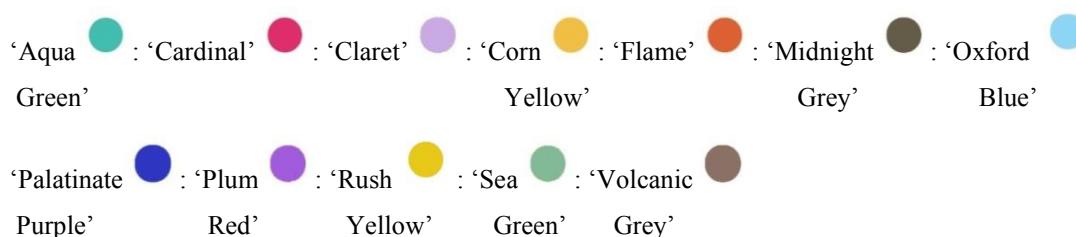
There was a trend for the colour to initially develop as a smudge. As the intensity of current increased a more defined circle was created. At 20mA, the dyes developed into a definite dot with greater or lesser degrees of smudging. As the current increased further, this dot developed a halo of colour around its circumference. At the higher currents the dye appeared to spill out and 'bleed' as though the dot had become saturated with dye. This then caused the circular shape to smudge. At times the 'bleeding' or halo effect that appeared in the photographs was not visible to the naked eye.

Contrary to the results in Section 5.3.5 and 5.3.6, there was no staining of the substrate by the 'Flame' and 'Cardinal' dyes when they were developed by the UV LEDs.

At 20mA a fade pattern was established and there was a general trend in the dyes starting to bleed. As previously stated, the LEDs are not to be routinely safely used at greater than this current. Therefore, taking these factors into consideration, testing the appearance and fade rates of the dyes with 370nm UV LEDs will only be carried out at a current of 20mA for each of 2, 5 and 10 seconds.

5.7.2.4 Measurement of printed photochromic dyes developed by 370nm LEDs

The Reversacol dyes used for testing were:



LEDs with a peak wavelength of 370nm were available with either a flat wide viewing lens or a domed narrow viewing lens. A domed narrow viewing lens LED, with a 4mm lamp size, was used to develop the dyes [5.37]. This enabled the effect a different lens shape had on each dye's development to be observed. The appearance and fade rates of the dyes at a current of 20mA for each of 2, 5 and 10 seconds was observed, following steps 1-6 in Section 5.7.2.2.

Observations:

The following observations were made:

- actual hue
- intensity of colour
- spread and bleeding
- fade time

Results:

Figure 5.83 and Table 5.17 show the results of the observations of the printed photochromic dyes when exposed to 370nm at a current of 20mA. Results for the fade rates of individual dyes can be seen in See Appendix R.3.

Comparison of fading times:

Figure 5.83 displays the fade times for each dye at 2, 5 and 10 seconds exposure. The results in Table 5.17 show that the order of fading for each time of exposure is relatively consistent. The slower fading dyes showed a definite increase in fading time as the exposure time increased. It is important to note that if one dye moves position or another is added to the list the placement of numbering is altered. Although there is some movement in the order of fading, when comparing the dyes with those developed by 400nm of UV light, the slower fading dyes and the faster fading dyes continue to be at opposite ends of the table. 'Rush Yellow' developed when exposed to 370nm of UV light so it was included in these graphs.

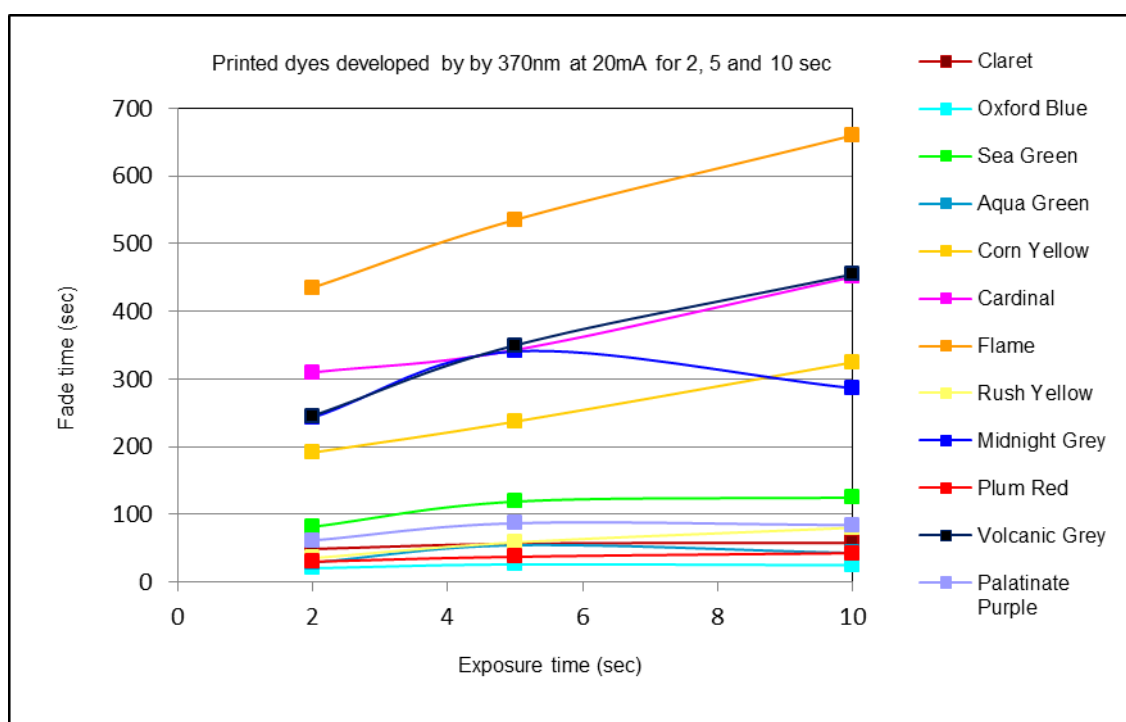


Fig. 5.83 Printed photochromic dyes developed by 370nm LED at 20mA for 2, 5 and 10 seconds

Dye	2 second exposure	5 second exposure	10 second exposure
‘Oxford Blue’	1	1	1
‘Aqua Green’	2	3	3
‘Plum Red’	3	2	2
‘Rush Yellow’	4	5	5
‘Claret’	5	4	4
‘Palatinate Purple’	6	6	6
‘Sea Green’	7	7	7
‘Corn Yellow’	8	8	9
‘Midnight Grey’	9	9	8
‘Volcanic Grey’	10	11	11
‘Cardinal’	11	10	10
‘Flame’	12	12	12

Table 5.17 Fading order of each of the dyes at 20mA

Table key

1= exhibits least of this property (in this case fastest to fade)

12 = exhibits most of this property (in this case slowest to fade)

Experimental errors:

Target exposure time	Actual exposure range	Average exposure	Standard deviation
2	2.05 - 2.31	2.25	0.08
5	5 - 5.52	5.29	0.12
10	10.17 - 10.36	10.25	0.05

Table 5.18 Target and actual exposure times in seconds

When developed at 20mA the following anomalies occurred. At 5 seconds exposure, ‘Volcanic Grey’ and ‘Cardinal’ cross over and ‘Rush Yellow’ and ‘Claret’ cross over. At 10 seconds exposure ‘Corn Yellow’ and ‘Midnight Grey’ cross over. Therefore, repeat experiments were made at 20mA for 5 seconds.

5.7.2.5 Repeat experiments were made at 20mA for 5 seconds

The process described in Section 5.7.2.4 was repeated three times at 20mA for five seconds to establish consistency of results. In practice, the 5 second exposure ranged from 5.05–5.34 with an average exposure time of 5.2 and a standard deviation of 0.1.

Results and Discussion:

Figure 5.84 shows the results of the repeat experiments. Results for the fade rates of individual dyes can be seen in Appendix R.4.

In the repeat experiments the order of fading of the dyes maintained consistency, indicating reliability in their behaviour when used in this medium and developed in this way.

When comparing the results of the dyes exposure to 370nm (Table 5.19, p.151) with their exposure to 400nm (Table 5.15, p.142), it can be seen that the order of fading was relatively consistent with the exception of 'Cardinal'. It slowed down in fading time (moving three places) when developed by 370nm of UV light. 'Corn Yellow' also moved closer to the slower end of the fading order. The fade times of all of the dyes were consistently faster when developed by 370nm than by 400nm.

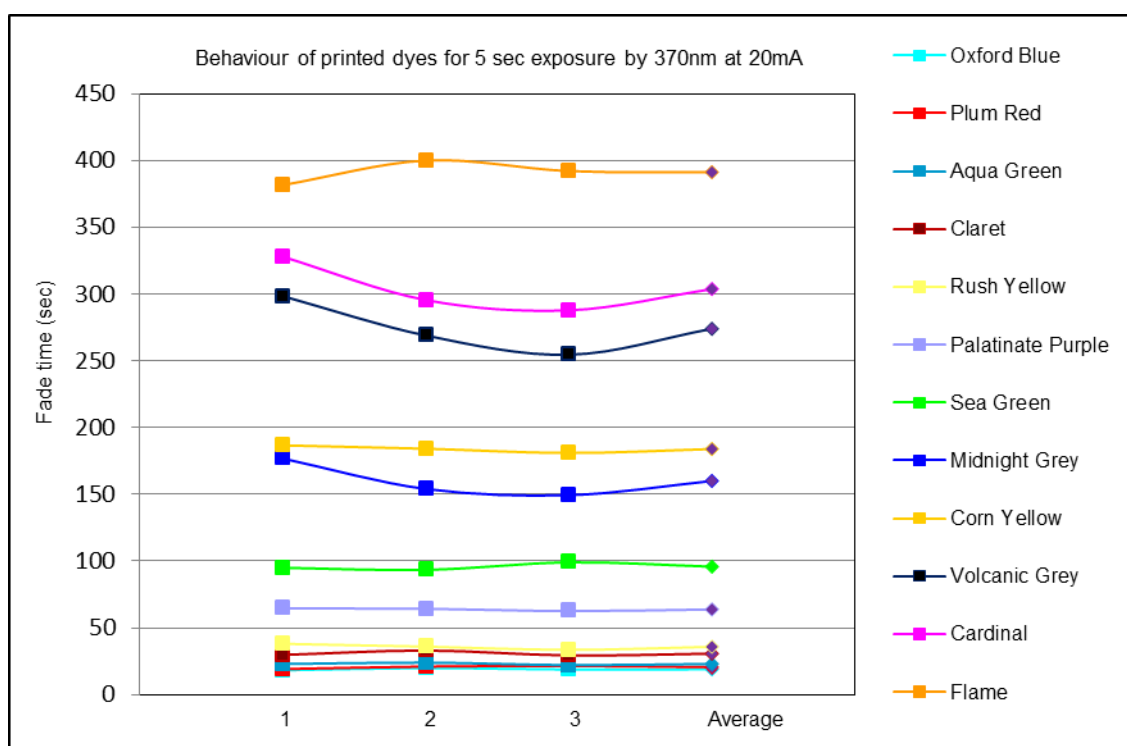


Fig. 5.84 Repeat experiments of printed dyes with 370nm LED at 20mA current for 5 seconds
The purple diamond at the end of each row marks the average fade time for the dyes.

Dye	5 second exposure
‘Oxford Blue’	1
‘Aqua Green’	3
‘Plum Red’	2
‘Rush Yellow’	5
‘Claret’	4
‘Palatinate Purple’	6
‘Sea Green’	7
‘Corn Yellow’	9
‘Midnight Grey’	8
‘Volcanic Grey’	10
‘Cardinal’	11
‘Flame’	12

Table 5.19 Average of fading of printed dyes at 20mA for 5 second exposure

Table key

1= exhibits least of this property (in this case fastest to fade)

12 = exhibits most of this property (in this case slowest to fade)

Colours and marks made:

According to the literature most of the dyes develop more strongly at 370nm than at 400nm [5.38]. Although there was not a noticeable increase in intensity of the colour of the dyes when developed by the 370nm LED, ‘Rush Yellow’ (that did not develop at 400nm) now developed a pale yellow colour (Fig. 5.85) and ‘Oxford Blue’ (barely visible when developed by 400nm at each current and time frame) now appeared lilac (Fig. 5.86). ‘Cardinal’ developed more strongly in colour (Fig. 5.87), which may account for its slower fading time, and ‘Volcanic Grey’ developed a slight mauve tinge.

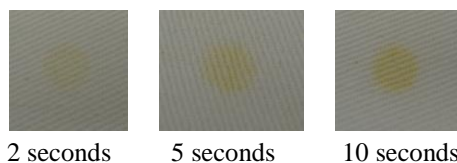


Fig. 5.85 Printed ‘Rush Yellow’ dye developed by 370nm at a current of 20mA at each of 2, 5 and 10 seconds

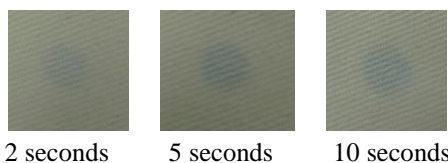


Fig. 5.86 Printed ‘Oxford Blue’ dye developed by 370nm at a current of 20mA at each of 2, 5 and 10 seconds



Fig. 5.87 Printed 'Cardinal' dye developed by 370nm at a current of 20mA at each of 2, 5 and 10 seconds

The domed narrow viewing lens of the 370nm LEDs resulted in the dyes developing a neat, circular shape with a distinct lack of 'bleeding', as illustrated in Figures 5.85-5.87. The marks made by both the 370nm and the 400nm lenses are reminiscent of the pointillist technique referred to in Chapter 4.

Based on the results obtained it has been shown that there is a consistency in the fading order of the printed dyes when they are developed by both the 370nm and the 400nm UV LEDs. Therefore, these results are able to be utilised when planning design work.

The difference in the hue and shade of some of the dyes when developed by 370nm and 400nm of UV light showed how the wavelength developing the dye affects its resulting colour. Observing each of the dyes as they were developed by a range of UV LEDs, for example, from 360nm-410nm, would show the strength of colour development of each dye at each wavelength. This would give a larger colour palette for use within design work and would be a very interesting area to explore in future work.

5.7.2.6 *Measuring extruded photochromic dyes developed by 400nm LED*

The Reversacol dyes used for testing were:



A 400nm LED with a 5mm lamp size and a round lens shape [5.39], was used to develop the extruded photochromic dyes at a range of currents and exposure times to observe their appearance and fading. See Appendix R.5.

Observations:

The following observations were made:

- actual hue
- intensity of colour

- spread and bleeding
- fade time

Results:

Figures 5.88-5.90 and Table 5.20 show the results of the observations of the extruded photochromic dyes when exposed to 400nm at a range of currents. Results for the fade rates of individual dyes can be seen in See Appendix R.6.

‘Sea Green’ was not developed after 5mA at 2 seconds and not all of the dyes were developed after 70mA as they took a long time to fade. All of the fade times for ‘Sea Green’ and the fade times for ‘Midnight Grey’ at 70mA were not added to the graph because of their long fading times. Several of the dyes did not develop when exposed for 2 and/or 5 and 10 seconds at the 1mA current (‘Volcanic Grey’, ‘Flame’, ‘Corn Yellow’ and ‘Midnight Grey’). ‘Cardinal’ did not develop consistently until exposed to the 20mA current, nor ‘Oxford Blue’ until exposed to the 30mA current.

Comparison of Figures 5.88-5.90:

Figures 5.88-5.90 show the exposure time for each dye when developed for 2, 5 and 10 seconds. Although they show that there was some crossing over of fading times, Table 5.20 shows that the order of fading for each dye over each time period at 20mA was relatively consistent.

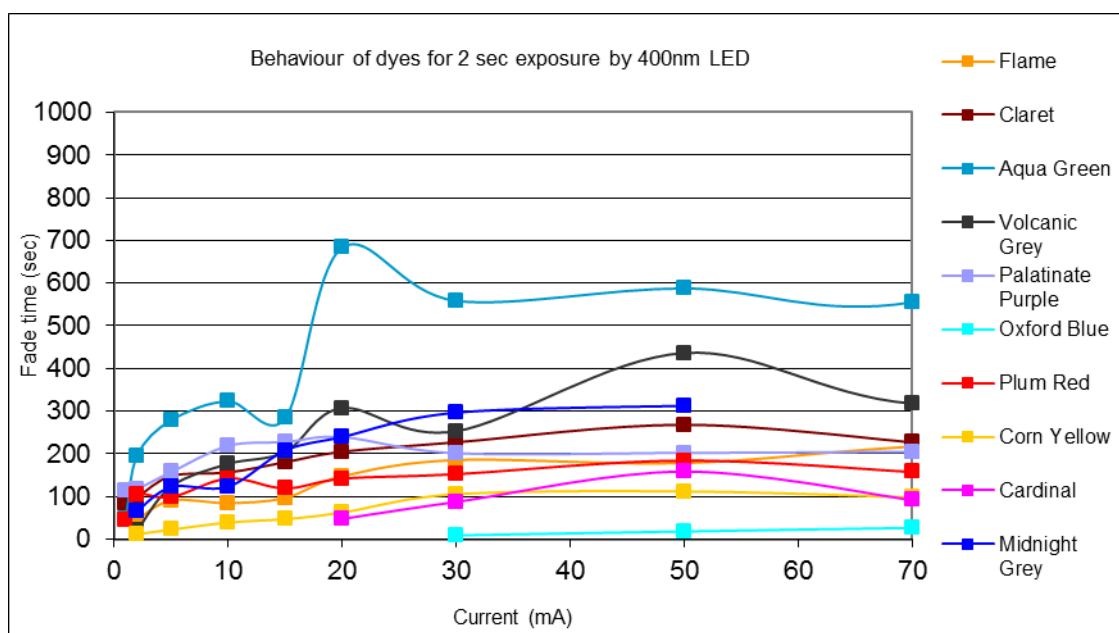


Fig. 5.88 Results of photochromic dyes extruded in polypropylene developed by 400nm LED for 2 seconds

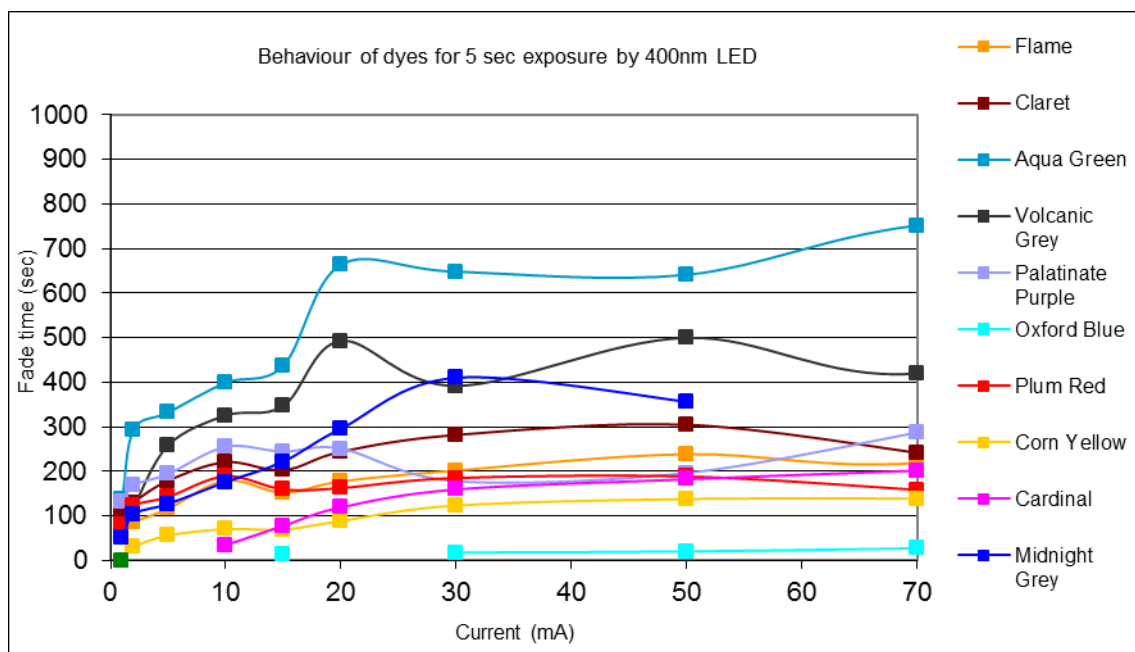


Fig. 5.89 Results of photochromic dyes extruded in polypropylene developed by 400nm LED for 5 seconds

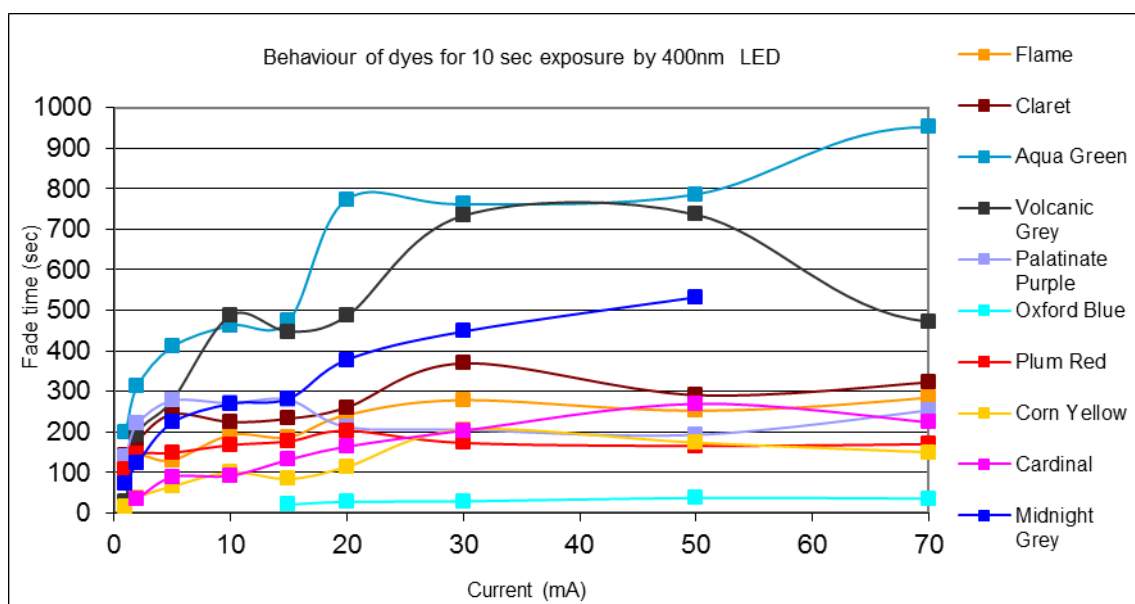


Fig. 5.90 Results of photochromic dyes extruded in polypropylene developed by 400nm LED for 10 seconds

Dye	2 second exposure	5 second exposure	10 second exposure
‘Oxford Blue’	-	1	1
‘Cardinal’	2	3	3
‘Corn Yellow’	3	2	2
‘Plum Red’	4	4	4
‘Flame’	5	5	6
‘Claret’	6	6	7
‘Palatinate Purple’	7	7	5
‘Midnight Grey’	8	8	8
‘Volcanic Grey’	9	9	9
‘Aqua Green’	10	10	10

Table 5.20 Order of fading of each of the dyes at 20mA

Table key

1= exhibits least of this property (in this case fastest time to fade)

10 = exhibits most of this property (in this case slowest time to fade)

Experimental errors:

Target exposure time	Actual exposure range	Average exposure	Standard deviation
2	2.02 – 2.68	2.36	0.1
5	5.21 – 5.83	5.39	0.09
10	10 – 10.52	10.35	0.09

Table 5.21 Target and actual exposure times in seconds

When developed at 20mA the following anomalies occurred. At 2 seconds exposure ‘Volcanic Grey’ and ‘Midnight Grey’ and ‘Palatinate Purple’ cross over, ‘Flame’ and ‘Plum Red’ cross over. At 5 seconds exposure ‘Midnight Grey’ and ‘Palatinate Purple’ cross over, and ‘Flame’ and ‘Plum Red’ cross over. At 10 seconds exposure ‘Palatinate Purple’, ‘Claret’ and ‘Flame’ cross over.

5.7.2.7 Repeat experiments made at 20mA for 5 seconds

The process described in Section 5.7.2.6 was repeated three times at 20mA for five seconds to establish consistency of results. In practice, the 5 second exposure ranged from 5.02–5.45 seconds with an average exposure time of 5.22 seconds and a standard deviation of 0.1. Results for the fade rates of individual dyes can be seen in Appendix R.7.

Results and Discussion:

Although the fade times of the dyes in the repeat experiments (Fig. 5.91) varied from those in Section 5.7.2.6, the order did not vary markedly, see Tables 5.20 and 5.22.

‘Midnight Grey’ appeared to fade more quickly in the repeat experiments and ‘Palatinate Purple’ more slowly. ‘Sea Green’ was not included in the repeat experiments as it took more than 40 minutes to fade in the initial experiments.

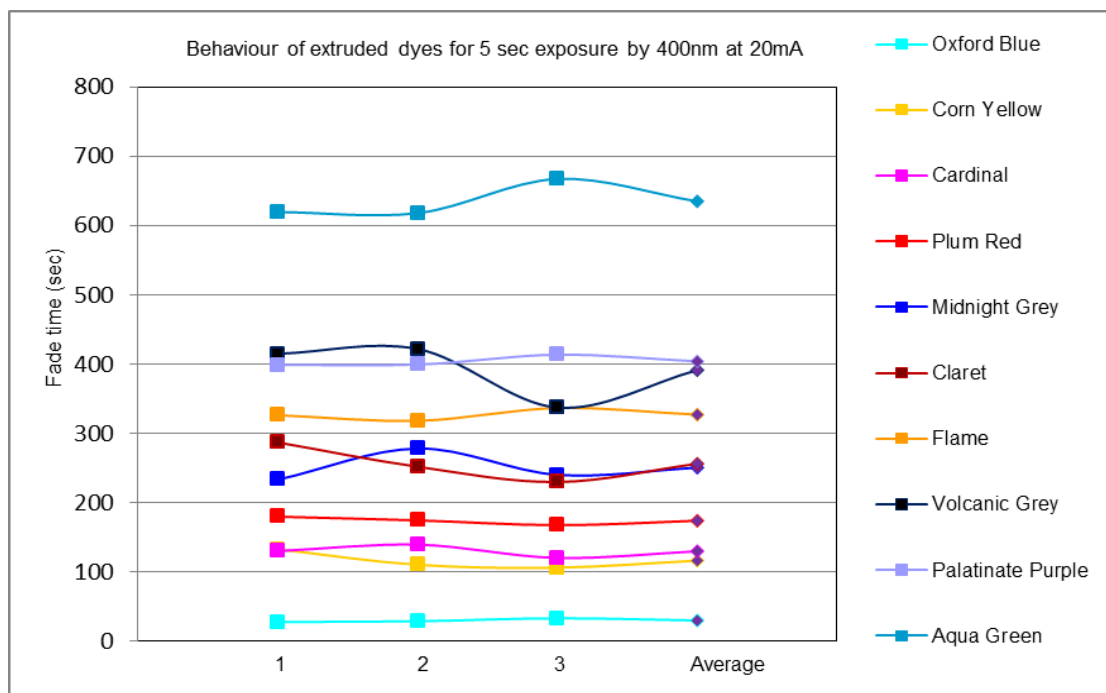


Fig. 5.91 Repeat experiments of extruded dyes with 400nm LED at 20mA current for 5 seconds
The purple diamond at the end of each row marks the average fade time for the dyes.

Dye	5 second exposure
‘Oxford Blue’	1
‘Cardinal’	3
‘Corn Yellow’	2
‘Plum Red’	4
‘Flame’	7
‘Claret’	6
‘Palatinate Purple’	9
‘Midnight Grey’	5
‘Volcanic Grey’	8
‘Aqua Green’	10

Table 5.22 Average of fading of extruded dyes at 20mA for 5 second exposure

Table key

1= exhibits least of this property (in this case fastest to fade)

10 = exhibits most of this property (in this case slowest to fade)

The fade times of the extruded dyes were consistently slower than those of the printed dyes with the exception of ‘Flame’ and ‘Corn Yellow’. Both of these dyes faded markedly more quickly in extruded form. Apart from ‘Oxford Blue’ maintaining the fastest fade time in both systems, the order of fading bears no resemblance to that of the

printed dyes (Table 5.13). ‘Sea Green’ faded very slowly when extruded, moving from the middle of the fading order when printed to the slowest fading time when extruded, by a large margin.

The fading order of the extruded dyes when developed by the LEDs was similar to when they were developed by natural UV light, with the exception of the ‘Cardinal’ dye that now faded more quickly.

Colours and marks made:

Figure 5.92 shows the colours and marks made by the developed dyes. Many of the dyes appeared to move closer to the red end of the colour spectrum when extruded than when printed, such as ‘Plum Red’ and ‘Claret’. ‘Midnight Grey’ and ‘Volcanic Grey’ each now contained red, developing into quite different colours. ‘Oxford Blue’ now appeared lilac and ‘Palatinate Purple’ became distinctly purple in colour. However, both ‘Corn Yellow’ and ‘Flame’ moved in the opposite direction on the colour spectrum, appearing more yellow than orange.

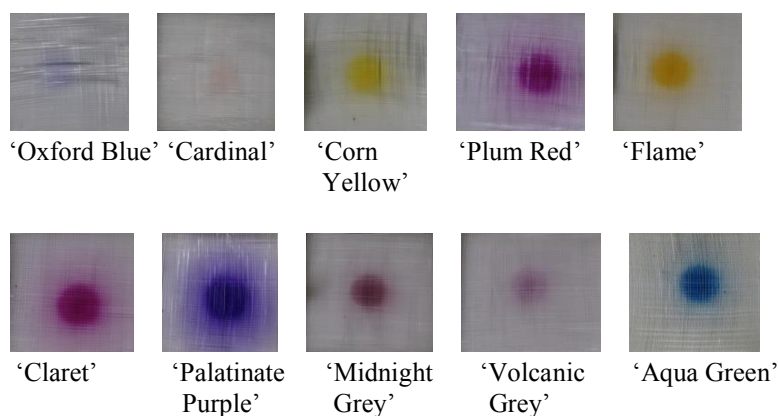


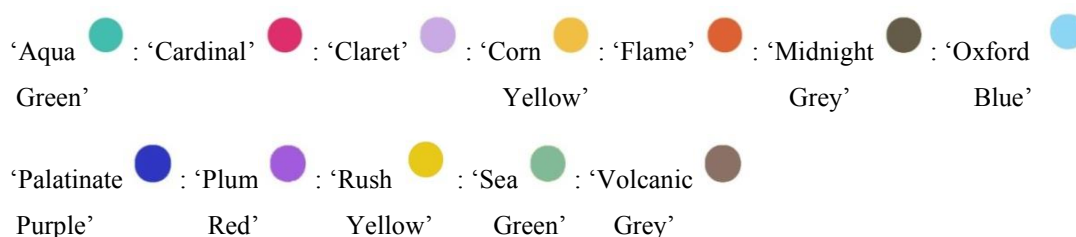
Fig. 5.92 Extruded photochromic dyes developed by 400nm LED at a current of 20mA for 5 seconds

As can be seen by comparing Figure 5.92 with Figure 5.81, the colours of the extruded dyes are much deeper in intensity than those of the printed dyes, and as previously stated, with noticeable differences in some of the hues that developed. This illustrates clearly that the choice of carrier system can significantly affect the shade of the product.

The dots created by the LED as the extruded dyes developed were very well defined, showing a greater contrast between the central circular shape and the ‘bleeding’ than when the dyes were printed. The ‘bleeding’ of some of the dyes, notably ‘Plum Red’, ‘Claret’ and ‘Palatinate Purple’, increased the surface area covered by the developed colour.

5.7.2.8 Measurement of extruded photochromic dyes developed by 370nm LEDs

The Reversacol dyes used for testing were:



The extruded photochromic dyes were developed with a domed lens, narrow viewing 370nm LED, with a 4mm lamp size. The appearance and fade rates of the dyes at a current of 20mA for each of 2, 5 and 10 seconds were observed, following steps 2-3 in Section 5.7.2.6.

Observations:

The following observations were made:

- actual hue
- colour intensity
- spread and bleeding
- fade time

Results:

Figure 5.93 and Table 5.23 show the results of the observations of the extruded photochromic dyes when exposed to a range of currents. Results for the fade rates of individual dyes can be seen in Appendix R.8.

Comparison of fading times:

Figure 5.93 shows the exposure time for each of the dyes at 2, 5 and 10 seconds and Table 5.23 shows the fading order of the dyes at each of the exposure times. 'Sea Green' was not developed at this wavelength as initial tests showed that it took so long to fade.

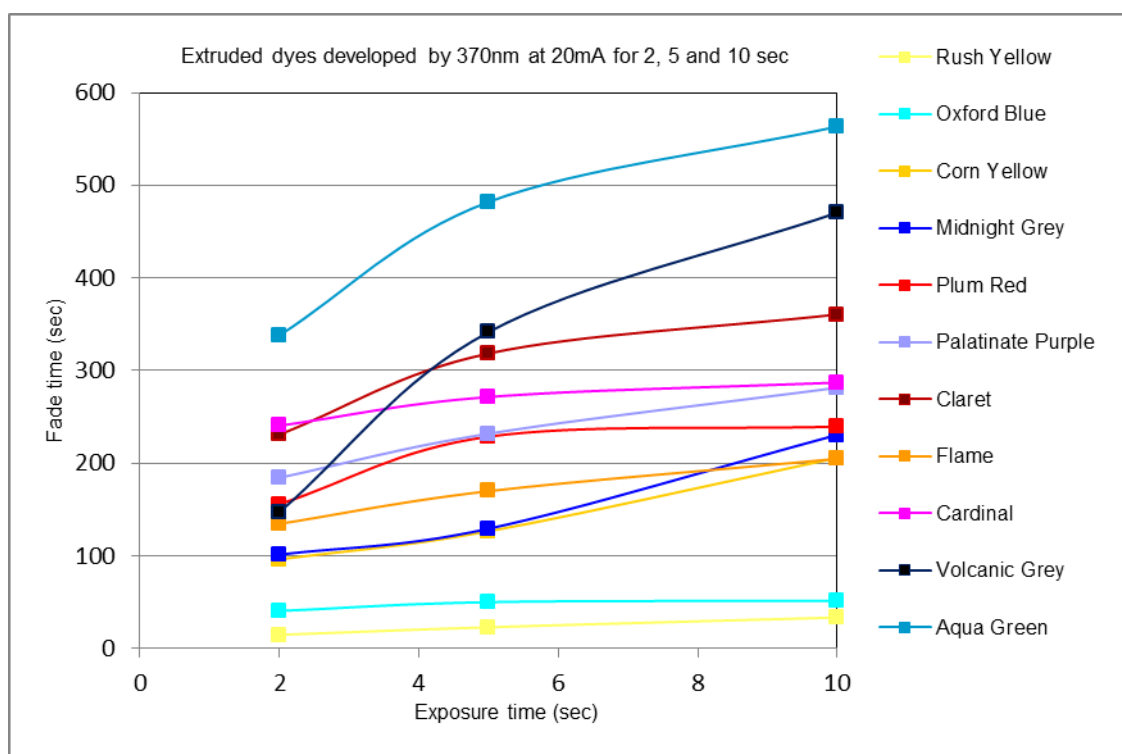


Fig. 5.93 Extruded photochromic dyes developed by 370nm LED at 20mA for 2, 5 and 10 seconds

Dye	2 second exposure	5 second exposure	10 second exposure
‘Rush Yellow’	1	1	1
‘Oxford Blue’	2	2	2
‘Corn Yellow’	3	3	4
‘Midnight Grey’	4	4	5
‘Flame’	5	5	3
‘Volcanic Grey’	6	10	10
‘Plum Red’	7	6	6
‘Palatinate Purple’	8	7	7
‘Claret’	9	9	9
‘Cardinal’	10	8	8
‘Aqua Green’	11	11	11

Table 5.23 Fading order of each of the dyes at 20mA

Table key

1= exhibits least of this property (in this case fastest to fade)

11 = exhibits most of this property (in this case slowest to fade)

Experimental errors:

Target exposure time	Actual exposure range	Average exposure	Standard deviation
2	2.08-2.33	2.25	0.09
5	5.08-5.37	5.26	0.09
10	10.02-10.36	10.24	0.11

Table 5.24 Target and actual exposure times in seconds

When developed at 20mA the following anomalies occurred. At 5 seconds exposure ‘Volcanic Grey’, ‘Claret’ and ‘Cardinal’, ‘Flame’ and ‘Palatinate Purple’ cross over. At 10 seconds exposure ‘Flame’, ‘Palatinate Purple’ and ‘Corn Yellow’ cross over. Thus, repeat experiments were made at 20mA for 5 seconds.

5.7.2.9 Repeat experiments made at 20mA for 5 seconds

The process described in Section 5.7.2.8 was repeated three times at 20mA for five seconds to establish consistency of results. In practice, the 5 second exposure ranged from 5–5.39 seconds with an average exposure time of 5.19 seconds and a standard deviation of 0.1.

Results and Discussion:

Figure 5.94 illustrates the fading pattern of the dyes. Results of the fade rates of individual dyes can be seen in Appendix R.9.

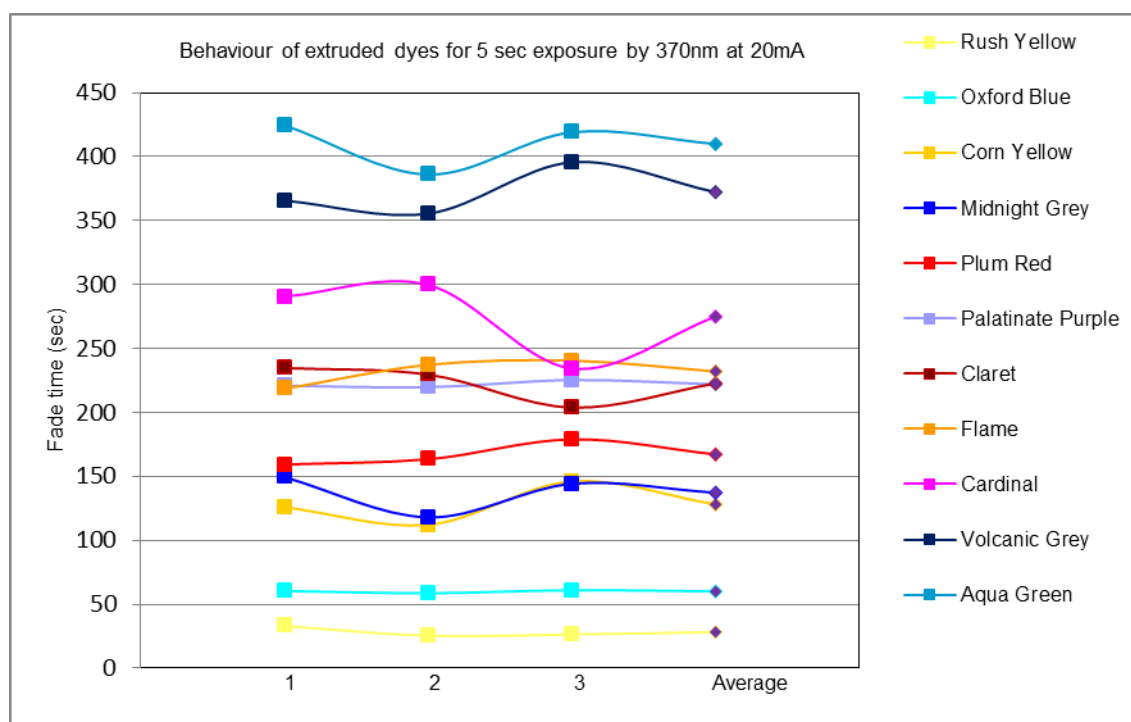


Fig. 5.94 Repeat experiments of extruded dyes with 370nm LED at 20mA current for 5 seconds
The purple diamond at the end of each row marks the average fade time for the dyes.

Dye	5 second exposure
‘Rush Yellow’	1
‘Oxford Blue’	2
‘Corn Yellow’	3
‘Midnight Grey’	4
‘Flame’	8
‘Volcanic Grey’	10
‘Plum Red’	5
‘Palatinate Purple’	6
‘Claret’	7
‘Cardinal’	9
‘Aqua Green’	11

Table 5.25 Average of fading of extruded dyes at 20mA for 5 sec exposure

Table key

1= exhibits least of this property (in this case fastest to fade)

11 = exhibits most of this property (in this case slowest to fade)

Figure 5.93 and Table 5.23 show that the fading times of the dyes are relatively consistent, with the exception of ‘Volcanic Grey’. This dye moved from being in the middle of the fading order at 2 seconds exposure to being the second slowest fading dye for 5 and 10 seconds exposure. As it was consistently placed second slowest in the fading order of the three repeat experiments, as shown in Table 5.25 and Appendix H(AC), the result at 2 seconds exposure may have been human error. The ‘Flame’ dye was also slower to fade, moving from the middle of the fading order, see Table 5.23, to the slower end of the fading order, see Table 5.25, in the repeat experiments. Although there was some crossing over of the dyes, particularly ‘Cardinal’ and ‘Claret’ (Fig. 5.94), these results show the benefit of repeat experiments.

Figure 5.93 shows that all of the dyes showed an increase in fading time as the exposure time increased.

The fading times of the dyes were consistently faster when developed by 370nm of UV light and their order of fading was also completely different when they were developed at this wavelength than when developed by 400nm of UV light. These results may indicate that the dyes are less stable in this medium than when printed.

Colours and marks made:

As when printed, the 370nm LED created neat circular dots of colour on the monofilament with distinctly less ‘bleeding’ (Figs. 5.95-5.96) than when the dyes were developed by the 400nm LEDs.



Fig. 5.95 Extruded ‘Oxford Blue’ dye developed by 370nm at a current of 20mA at each of 2, 5 and 10 seconds



Fig. 5.96 Extruded ‘Cardinal’ dye developed by 370nm at a current of 20mA at each of 2, 5 and 10 seconds

Additionally, as with the printed dyes, ‘Rush Yellow’ developed a light yellow colour when developed by 370nm of light. ‘Oxford Blue’ and ‘Cardinal’ responded markedly better to this wavelength with the ‘Cardinal’ dye developing a salmon colour. An increase in intensity of colour, as the exposure time increased, could also be seen.

5.7.2.10 Conclusions

A process of testing how the dyes respond to UV LEDs has been established, enabling the fade rates of the dyes within the two systems, i.e., both printed and extruded, to be determined.

The fade profiles and the variations in the colours of the dyes showed that they respond differently when used in either form. The practical result is two colour palettes - one based on fade rates and one based on strength and shade of colour. This could serve multiple purposes within design work if mixed media were to be used. For example, if a slow fading green colour was required the ‘Aqua Green’ monofilament may be used and if a fast fading green was required the printed ‘Aqua Green’ may be the preferred choice. Alternatively, if a slow fading orange colour was to be dominant, the printed ‘Flame’ dye may be used. Therefore, the effects that can be created by using a combination of these two different forms of media will be explored in the forthcoming design development work.

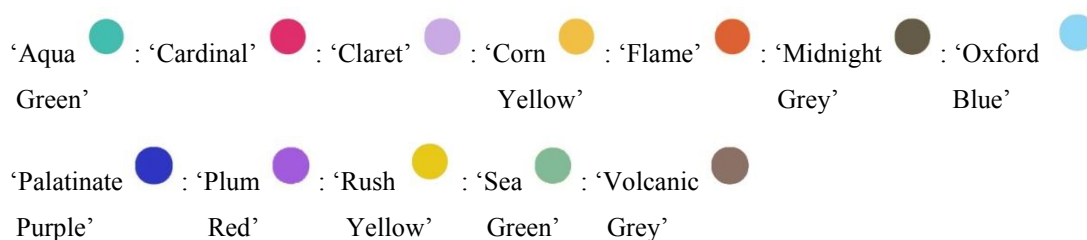
The marks made by the LEDs on both substrates are similar to the brush marks used by the French Impressionists and the subsequent pointillist technique that was developed. Those made by the round lens shape of the 400nm LEDs, that created smudging or ‘bleeding’ of the central circle, may give a more painterly effect when used collectively than the neater circles made by the domed narrow viewing lens of the 370nm LED.

Although developing the dyes using two different wavelengths of UV light would provide a larger range of colours and the neat circular shape and the softer ‘bleed’ marks created by the different lens shapes of the LEDs would provide different ‘brush’ marks for use within an image or design, there is a difference in the lengths of the pins of the 370nm and the 400nm LEDs and this would cause practical problems when building an LED array. The distance from the bulb to the fabric would differ between wavelengths causing an inconsistency in the strength of light developing the dyes thereby under utilising the shorter stemmed 370nm LED. In this scenario, there would not be any benefit gained from developing the dyes using the two different wavelengths of light. Additionally, the 370nm LEDs are at the lower end of the UV spectrum than the 400nm LEDs, therefore safety of the user is also a concern. Consumer nervousness and response to a UV light source was also considered. After evaluating these factors it was decided to build an array that consisted solely of 400nm LEDs. Based on the conclusions drawn in Section 5.7.2.3, the maximum current sent to the LEDs would be 20mA.

5.7.3 *Developing dyes with fluorescent light*

‘Palatinate Purple’ and ‘Sea Green’ photochromic dyes have excellent visible light activation and some colour change can occur under indoor office strip lighting [5.40]. As the resulting design product would be placed in an interiors setting, where fluorescent light is present, its affect on the dyes’ development needed to be observed.

The Reversacol dyes used for testing were:



Observing the responses of the dyes, in both printed and extruded form, to fluorescent light would show the extent of any colour development and how this may influence design decisions. The printed samples were observed first, followed by the extruded samples. See Appendix S.

Observations:

The following subjective observation of the dyes was made:

- colour development

Results of printed samples:

Four of the printed substrates showed only a very slight colour change after 2 minutes of exposure to fluorescent light, see Table 5.26. No further discernible colour development of any of the dyes was observed over a 20 minute time period.

Length of exposure	Colour change	Dyes affected
upon opening sketch book	no discernible change	-
2 minutes	developed very slightly in colour	'Flame' 'Midnight Grey' 'Palatinate Purple' 'Sea Green'
20 minutes	no discernible change	-

Table 5.26 Printed dyes under fluorescent light

Observations:

The following observation of the monofilament dyes was made:

- colour development

Results of extruded samples:

Three samples of polypropylene, 'Aqua Green', 'Claret' and 'Palatinate Purple', showed only very slight colour development after 30 minutes of exposure to fluorescent light. No further discernible colour development was observed in any of these samples after the 60 minutes of exposure, see Table 5.27.

Length of exposure	Colour change	Dyes affected
10 minutes	pale green	'Sea Green'
15 minutes	a little deeper green	'Sea Green'
30 minutes	very, very light green very, very light pink very slight shade purple deeper green	'Aqua Green' 'Claret' 'Palatinate Purple' 'Sea Green'
60 minutes	no discernible change	-

Table 5.27 Extruded dyes under fluorescent light

‘Sea Green’ had developed a pale green colour after 10 minutes. It continued to develop over a 30 minute time period with no discernible colour development thereafter, see Table 5.27.

Discussion:

In this instance, the fluorescent lighting was larger and closer to the substrates than would be expected in an average home environment, where lights are usually smaller and more widely laid out to create a certain ambience. The very slight colour development on the cotton substrates may give a faint residual background colour to the fabric that would need to be taken into consideration.

With the exception of ‘Sea Green’, the extruded dyes, although markedly stronger in colour than the printed dyes, appear to be less affected by the fluorescent lighting.

5.8 Summary

The experiments carried out in this chapter were to gain an understanding of working with, and the working capabilities of, photochromic dyes. The initial tests gave an important practical appreciation of the difficulty of using dyes that cannot be seen and day to day working habits that needed to be altered. When idiosyncracies occurred, repeat experiments were performed. It was then established that these idiosyncracies were part of the way the dyes behave and needed to be accepted instead of assuming that a procedure or result was incorrect.

Tests have shown that the dyes can be used within designs of minimal complexity, utilising their movement and colour, to create a three dimensional effect. Although the placement of a moving dye beside a static pigment and a moving dye beside another moving dye created these effects, the latter combination, i.e., using only photochromic dyes, gave the most organic and ephemeral result.

Although the pictorial imagery of, for example, the tree with emerging fruit, appeared to hint at something else occurring, the abstract images enabled colour interactions to be observed more easily. When using only square shapes, the colours appeared to move forwards and then recede, displaying greater depth. When colour covered the whole substrate there appeared to be more depth to the overall piece.

Based on the results of Section 5.7, an LED platform will be created to develop the dyes and explore their capacity to make an image appear then disappear whilst another image emerges into view, replacing the original image. The intention is to retain the fluidity of the dyes' movement whilst controlling their appearance and disappearance as they effect colour change. The circular marks that the LED's make when developing the dyes will be used to build up designs and will influence the motifs to be created.

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Chapter 6

Development of Artificial Light Sources and Recording the Dyes' Movement

All matter comes from light ... light is life, everything comes out of light ... light is the
essence of art [6.1].

Development of Artificial Light Sources and Recording the Dyes' Movement

6.1 Introduction

The ability of the colours and movements of the dyes to capture emotions ranging from joy to sadness set the parameters for exploring the extent of visual narrative that could be achieved using photochromic dyes on a textile substrate. LEDs, set out in an array format, would be used to develop the dyes for this purpose. This chapter sets out the factors that informed my decisions about the process of building the LED arrays, how they worked, their parameters, and the recording and presentation of the design work that was developed using these devices. The design observations are explained separately in Chapter 7, to make it easier for the reader.

Having a light source custom built was an informative experience. I was not expecting to have to do this however, as readymade UV LED arrays were not available, it was necessary. As a textile designer lacking electronics hardware and software insight, working with the distinctly different fields of science and technology brought a new awareness of how other disciplines work. Fortunately, in an inverse way, naivety of, and lack of resonance with, the engineering field was beneficial. My design expectations for the light source were not restrained, whereas an understanding of the complexity of the task may have dampened my ambition or expectations. The process involved working closely with electronics hardware and software engineers so that the light sources could be built and programmed to enable the capabilities of the dyes to be explored.

The first small array was manually controlled after the desired pattern had been programmed into its software. The dyes were then observed developing and fading whilst the capabilities of this array were explored.

Concurrently, an appropriate means for recording and viewing this work was sourced. The dyes initially continued to be photographed and then they were filmed. Filming proved invaluable for recording the movement of the dyes to enable repeated viewing and reflection on the work. Additionally, an appropriate software programme into which the videos could be uploaded ultimately enabled the concept of how the dyes would appear, as they developed and faded in a larger format, to be seen.

After considering the results of the tests on the small array, a larger and software driven array was built. Its aim was to set up a test environment with the least amount of manual input of data whilst giving flexibility for testing the characteristics of the dyes. By learning how to write the text data for its software, I was able to observe how this translated into the lights of the array being switched on and off leading to the creation of light patterns that could change. The dyes were developed using these patterns and the outcomes noted. Progressively the software was altered to broaden the scope for design work.

6.2 Development of Small Array

As illustrated in Chapter 5, the development of the dyes using LEDs showed how this form of light source created circular shapes or dots on the textile substrate. These marks were reminiscent of the pointillist dots and daubs used by the French Impressionists, computer pixels and mosaic tiles, and could potentially be used to build up a picture. Therefore, a platform of LEDs was needed so that the interactions of the colours of the dyes, when they were developed by this light source, could be observed. The potential of this device as a means for exploring the project aim could then be ascertained.

6.2.1 Objectives of small array

An array was required that was able to

- control the intensity of the current delivered to the LEDs
- control the length of time the assigned current was delivered
- programme the LEDs to emit light in prescribed patterns
- develop the defined light patterns in series

6.2.2 Fulfilling parameters of small array

After discussing the requirements of the small array with the University electronics hardware engineers, they were able to build a square array, consisting of 64 LEDs arranged in eight rows of eight, as shown in Figure 6.1.



Fig. 6.1 Small array

The array was built so that

- it could be turned on and off manually by a switch
- initially, when the lights were switched on to develop the dyes, spaces in between the LEDs left areas of undeveloped dye on the textile substrate. To minimise the size of these areas, the light bulbs were placed side by side, with as little space as possible between them.
- initially, a 5mA current passed through the LEDs. However, testing of the individual LEDs had shown that a higher current setting gave deeper colour strength and increased the surface spread of the developed dyes. Therefore, the current going through this array needed to be increased. This request led to the testing of an LED using a bench power supply, pulsing the equivalent of a 20mA current over a period of a couple of days. This test showed that the diode would work at the increased current. The existing array was then modified to enable the power supply to the whole array to be increased to a maximum 20mA of current.
- the intensity of the current delivered to the LEDs was able to be controlled manually, using an intensity dial
- the length of time a particular current was delivered to the LEDs was controlled manually, using a stop watch
- a freeware software programme that enabled light patterns to be programmed into the array, in series, was used. Each time I wanted to develop the dyes I sketched a series of light patterns, in sequence, illustrating exactly how the lights were to be displayed on the array. The electronics hardware engineer would disassemble the array and then re-programme it, using the freeware software that had been installed on a computer in the engineer's workshop, so that it displayed the light patterns.
- changing from one light pattern to another, in series, could then be carried out manually, by repeatedly pressing the switch on the array box.

A Perspex covering was secured over the LEDs to protect the user from the UV light emitted. The initial cover was yellow as this was readily available and offered a protective covering. Although its yellow colouring meant that the true colour of the underlying dyes could not be seen, their movement could be observed. Therefore, a series of observations of the dyes was carried out whilst clear Perspex was being sourced.

A sample of clear museum grade Perspex was acquired. To ascertain its UV resistance, it was tested using a Shimadzu Spectrum Photometer model No.UV3100. This showed that the Perspex blocked light below the wavelength of 410nm. With a clear cover the true colour of the dyes could be seen therefore a further series of tests, using this array, followed.

6.2.3 Summary

Although this small array enabled testing of the initial concept, it was static with regard to sequencing. This limited the number of experiments that could be carried out within the time available. Furthermore, each time the light pattern needed to be changed the array had to be taken to the main University campus over an hour's travel away. Additionally, any alteration to the intensity of current applied to the whole array. The current to columns or individual LEDs could not be changed. A larger independently programmable light source would better illustrate the potential for developing photochromic dyes in this way, and also allow greater independence for the user, therefore a second array was built.

6.3 Recording of Dyes' Movement

The ephemeral nature of the dyes appearing and disappearing posed a practical research problem as they were only visible when they were being developed by the light source, and for a short period thereafter. A form of recording the dynamic quality of the dyes, as well as the design testing and developmental work, was needed. There were various challenges involved in finding a suitable means for recording the work.

6.3.1 Recording

The development of the dyes with the initial array was first captured by a small digital camera. This simple exercise demonstrated that being able to playback and observe the colours of the dyes and their movement was informative, as well as a necessity. It would allow repeated observations of the dyes without having to repeatedly use the array, repeatedly use the dyes, or wait for them to fade. Photographs were valuable for recollection and later analysis and planning, however still images do not capture all moments. As the recording and presentation of the videos was interlinked, various means of solving this problem were trialed concurrently:

- a small digital camera with a video application was used to record the initial tests, however there was a limitation on the length of time the camera could

record in each instance, and its small memory capacity was insufficient for the amount of filming being carried out.

- a handheld video camera was obtained from the audio-visual department on this campus. Unfortunately, its capacity for close-up, zooming in and focusing on the array, was limited. Additionally, transferring the videos from camera to computer would have required an additional piece of hardware to be added to the computer.
- further enquiries at the Audio Visual and Graphics departments of the main University campus did not provide a resolution.
- the close-up and focusing features on a larger-sized digital camera proved suitable for the needs of this project. It was also compatible for use with Quicktime and Flash Player. Using a camera tripod eliminated the movement caused by its handheld use.

6.3.2 *Presentation*

A format was needed to display the recordings of some of the design developmental work. Three alternatives were available:

- A table was set up manually in a webpage using html. Code was written to embed the movie files, arrange their placement and format their size. Each cell of the table contained one of the videos. Initially the video controls were visible on the screen as part of the file. Altering the code was able to remove these from view so that a more cohesive image could be seen. Unfortunately, having more than one file in the table at a time resulted in the videos running at slower than their 'real time' pace. Although this format was useful for observing the dyes for their colour and proportion, inaccurate viewings of the dyes' speed of movement would be given.
- Final Cut Express & Media Edit3, both software programmes used on Apple computers were explored, however Microsoft compatible programmes and computers were being used for this project.
- Adobe Flash CS3 Professional, a multimedia software programme, enables animation to be created. The video files used to record the array displays were uploaded into this programme. Testing of multiple videos and the scale of video size showed that their real-time movement was not compromised. It also allowed for the videos to be cropped and proved a very suitable design environment for displaying videos of the project work.

6.3.3 Summary

Photography proved very useful for recording the dyes when they had been developed by natural UV light and for analysis of their characteristics and actions. However, as they are a moving medium and it was this factor that was to be explored, it became evident that it would be necessary to film the dyes. This means of recording also facilitated the development of ideas, so that their practicality, or not, could be analysed and subsequent work planned. The software programme Flash provided the platform in which work could be viewed and enabled concepts that were in the mind's eye to be illustrated.

6.4 Development of Large Array

The results of the observations on the small array demonstrated that there was potential for further design development with these dyes using this form of light source. Therefore, a larger array, that could be used to develop the dyes in prescribed patterns, was built.

6.4.1 Objectives of large array

LEDs are ordinarily used for simple light displays, such as the flight schedule boards in airports. In this project the UV LEDs were to be used in a manner for which they had not been designed, that is, as part of an array and to develop photochromic dyes to fulfil a design aim. As the designer, being able to control the driving of the LED array to create patterns, as well as the timing and intensity of the lights, was important. This objective meant the array needed to be software driven, not electronics driven.

From a design perspective a software-driven text file interface would facilitate

- controlling when, and for how long, each LED was switched on and off
- controlling the intensity of each column of LEDs
- the observation of the interactions of the colours of the dyes
- changing patterns locally so that the number and frequency of tests of design patterns could be increased
- the design process overall
- greater independence and effectiveness in my research practice

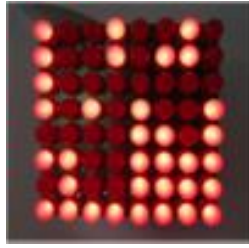


Fig. 6.2 Test matrix

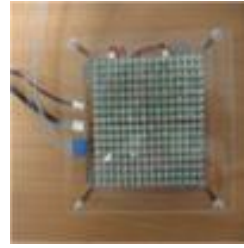


Fig. 6.3 400nm array

6.4.2 Fulfilling parameters of large array

The designer, the electronics hardware engineers and the software engineer met to discuss the requirements for the array, with the following outcomes

- the electronics hardware engineers developed a test matrix using 64 (8x8) red LEDs (Fig. 6.2). Red LEDs were used as they were far less expensive than UV LEDs, emitted no UV light and were suitable for testing software.
- the software engineer developed and tested a software programme for this array.
- the software was designed in such a way that multiple patterns could be entered through a text file interface, with a time delay for each pattern so they could be run continuously through the LED device.
- when the software was proven to work on the single red LED array, the electronics engineers made a larger array consisting of four red LED matrices.
- the software engineer developed software to drive the four matrices.
- once this software was proven to work, the hardware engineers made an array using 256 (16x16) 400nm LEDs (Fig. 6.3).
- the software developed for the four red LED matrices was then successfully tested on the UV LED array.

The LEDs and electronics of the array needed to be protected. The precaution of shielding the user from the 400nm light was also important. Therefore, a ready-made polycarbonate box was customised to fit the array, providing protection for it as well as safe usability and portability.

6.4.3 Development of software programming for large array

The software programme for the 8x8 red LED array was initially set up to allow

- any pattern of lights to be programmed into the array
- the amount of time that each light pattern was to be displayed to be defined in seconds before the next light pattern in the sequence played

The designer would specify the following in the format of a text file which would be read by the software

- the number of designs that would display
- the number of matrices used
- the intensity of the current sent to the matrices
- the amount of time, in seconds, that each pattern would be displayed

Once the programming had been developed for the 8x8 red LED array, it was used to gain familiarity with the writing of the software programmes. It also demonstrated that mimicking the French Impressionist film techniques with the light sources was possible. For example, Figures 6.4 and 6.5 show the movement of the lights progressively from left to right in a way that would develop the dyes to resemble the iris technique.

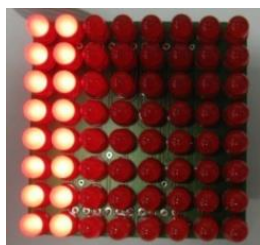


Fig. 6.4 8x8 red array

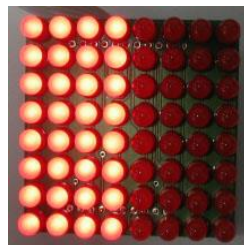


Fig. 6.5 8x8 red array

The larger (16x16) LED array was then built. As using the hardware and software of this array, in conjunction with the dyes, unfolded, the programming of the LEDs needed to be modified to increase the scope for design exploration and fluidity of movement of the dyes' development. These modifications were discussed with the software engineer who then altered the software programme. The modifications are set out below.

6.4.3.1 Intensity variation

Being able to change the intensity of the current that lit up the UV LEDs would give a degree of control over the development of the depth of colour of the dyes. Having a range of colour strengths from which to choose would assist with design development that was aimed at expressing the opposing feelings of joy and sadness.

Therefore, the software was modified to drive the four UV matrices and enable the intensity of each iteration to be defined on a scale of 1-15, with 0 being the lowest (lightest) and 15 being the highest (strongest) intensity. The number 15 is equivalent to

approximately 20mA, the numbers 7-8 are equivalent to approximately 10mA and the number 4 equivalent to approximately 5mA.

A series of simple patterns was specified using the text file which was then input into the software which drove the LED display to create the light patterns that would vary the intensity and the time of the UV light emitted by each diode in the array to develop the selected dyes. The intensity and length of time the dyes were developed affected the resulting photochromic colour to varying degrees.

6.4.3.2 Repetition control and time delay

The programming process would be simplified if the number of times a sequence of patterns was able to be repeatedly played could be nominated. Additionally, increasing the subtlety of the time delay intervals would assist with the ebb and flow of the dyes' development and the building of momentum and tension within a design.

The software was therefore further modified so it could specify how many times a sequence of patterns was to be displayed. If the defined value was any negative integer, then the loop would continue endlessly. Observing a pattern sequence running indefinitely through the array showed that programming a series of patterns to run consecutively, as part of a larger design sequence (that could continue an infinite number of times), would allow greater freedom within design development. Additionally, the time delay was changed from seconds to milliseconds. For example, the time of 0.8 of a second could be specified and would be written as 800ms. As the objective was to show a change of mood, and as some of the dyes would not be developed for very long, the fractions of time used would create greater subtlety within these short time frames. Examples are shown in Section 7.4.2.

6.4.3.3 Individual matrix intensity control

The ability to change the intensity of the current sent to the lights within each individual matrix would enable different strengths of colour to be developed by the LEDs on different parts of the substrate.

Therefore, the software was modified so that the intensity of current sent to each matrix could be individually controlled and differ from each of the other three matrices. A

series of simple patterns, using the different intensities within each matrix, was used to develop selected dyes, see Section 7.4.3.

6.4.3.4 *Column intensity control*

Controlling the intensity of the electrical current to individual columns of LEDs would enable pattern and colour development to be further refined. The intensity of the lights for one column was set, and after a period of time, e.g., 10 seconds, the next column was switched on. Each time a new column was switched on, the new intensity would apply to the other columns that were also switched on and a sense of movement, created by a flickering effect, would occur. Various data was written to observe the effects created and to understand how to programme the whole array, see Section 7.4.4.

Changing the intensity of the electrical current to individual LEDs within each column was not able to be put into effect due to the way the electronics of the array had been configured. It would have required different circuit boards and a very large circuit box that would have proven costly. Additionally, the technicians did not have the software or the time to develop the hardware. In this project, the design work would consider the size of the marks made on the substrate, their depth of colour and how they influenced the scale of the designs to be created, and this was not dependent on being able to control the current to individual LEDs. However, the building of an array in which the current to individual LEDs could be controlled would be worthwhile exploring in future design applications.

6.4.4 *Summary*

This larger sized array enabled patterns to be created more easily and the development of the dyes to be seen on a larger scale. The writing of the text data proved to be a creative exercise and part of the process of enabling design ideas to come to fruition. The progressive modifications to its programming enabled skill to be gained at using both the software and the hardware.

6.5 *Summary*

The small array enabled the dyes to be developed by a platform of artificial UV light. The intensity of the current to the LEDs and the amount of time the dyes were developed by the LEDs on this array were manually controlled. Light patterns were able to be created that then developed the dyes.

Filming proved to be an appropriate way of recording the movement and colours of the dyes. The presentation formats provided a way for the video files of the dyes to be uploaded so they could be viewed, enabling design work to be reviewed easily so it could be progressed.

The large array, with its increased complexity of hardware and software capabilities, enabled design ideas to be trialed. The refinement of the software programming meant that the dyes' development and movement could be further managed to explore the project aim.

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Chapter 7

Testing Dye Development using LED Arrays and Filming of Dyes

Testing Dye Development using LED Arrays and Filming of Dyes

7.1 Introduction

From the outset, parallels could be drawn between the equipment to be used for this project and that used by an artist or designer, raising the following questions: How would this medium of photochromic dye work? What sort of 'paint brush' would be used to apply the dyes to the substrate? How would that paint brush interact with the substrate? What sort of brush strokes would be made? What would the substrate be made of and what sort of texture would it have? Before designing with the dyes could commence, the appropriate tools had to be selected and some new ones developed.

The experimental work in Chapter 5 provided a working knowledge of how the dyes respond when developed by natural UV light. As the aim was to control their movement, they were then developed by artificial UV light in the form of LEDs. Testing showed their colours as they were developed at a range of currents and time frames, the marks they made on the substrate and their fading patterns, resulting in the LEDs being chosen as the form of light source for this project. In this capacity they would act as the paint brush, developing the dyes to create coloured dots that would emerge out of the cotton drill substrate. When the light from the LEDs was removed from the fabric, the dyes (and therefore any marks made) would fade away. However, before these results could be applied to build designs, a way of using the dyes in combination with the LEDs, in the form of arrays, needed to be addressed. As these were newly developed and unfamiliar tools I would need to find a way of working with them so they could be used effectively to achieve the project aim.

When photochromic dyes are exposed to sunlight the colours develop, overall, at the same time, although their intensity can be seen to be very subtly deepening. Their fading order, however, is visibly staggered. By using artificial UV light, the small array provided the opportunity to control the development of the dyes in a defined area, at a chosen time and for a chosen period of time. This meant that the order in which the dyes faded could also be managed. It was therefore important to observe the dyes as they were developed in this way by this device. A consequence of using the LEDs was the bright light that they each radiated as they developed the dyes. A way of managing this effect, in combination with the developed coloured dots, also needed to be worked out. Therefore, a range of light patterns was used to develop both individual colours and combinations of dyes, enabling the appearance of the marks made, as they

developed and faded on the substrate, to be seen and conclusions drawn as to how to best use the dyes and the LEDs of the array together. This initial testing gave encouraging results.

Simultaneously, a means of recording the dyes and of presenting the work so it could be easily viewed, thereby making the observations of the dyes and test work easier, was explored. The dyes were also observed during this process.

Based on the results of the development of the dyes on the small array, a larger array that was software programmable was built. A series of exercises was then carried out on this device to gain familiarity with its features as it developed the dyes.

7.2 Developing Dyes on Small Array

Two questions continually arose when contemplating using this light source - how would the different colours of the dyes be arranged on the substrate and how would the lights interact with those colours, that is, what sequence or arrangement of patterns would the lights follow to develop the dyes? Therefore, a series of light patterns was programmed into the small array to establish how to combine the development, the colours and the fading speeds of the dyes.

Method used:

Initially, all of the LEDs on the array were used to develop individual dyes. This enabled their colours, when developed as a group, to be observed. The LEDs then developed a simple motif. Reflecting on the French Impressionists' use of colour and mark making, a daub design printed in two colours was chosen. Thereafter, a series of light patterns was programmed into the array and used to explore the development and fading of the dyes and the capability of the light source. Although the yellow Perspex hindered observation of their colours, aspects of the dyes' development and movement were able to be observed whilst the clear museum grade Perspex was being sourced.

The tests were carried out using selected dyes based on their colour and/or speed of fading. The print pastes used in the tests were made using the relevant method as described in Section 5.2.1 or Section 5.2.2. The dyes were printed following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

For this series of tests, each light pattern was sketched out in pencil and given to the electronics engineer who then programmed the software within the array so that, by repeatedly pressing a button, the prescribed light patterns would develop in sequence.

Initial observations were carried out in a conditioned testing laboratory where the temperature was a consistent 17°-18.5°C, to minimise the effects that atmospheric conditions would have on the dyes. Testing was then moved to another conditioned testing laboratory in which the temperature was maintained at a consistent 20±2°C and 65±5% RH, more similar to the ambient temperature of a home. Although it is accepted that the average home environment is not controlled in this way, it is conceivable that the consumer who would be able to afford this sort of product may have a home, such as the one shown in the video *Living Tomorrow: house of the future* [7.1] that supported the creation of a sensitive environment, one conducive to works of art or design products that needed to be placed in particular conditions.

For each observation, the printed sample was placed under the Perspex cover immediately above the LEDs. As each light pattern developed the dyes it was photographed. The fabric sample was then removed from the array and photographed at the relevant intervals. When the array cover was clear the dyes were photographed immediately the LEDs were switched off and at the relevant intervals thereafter.

The current of the array was set at its strongest intensity, approximately 20mA, at this stage of the project, to achieve maximum strength of colour, for the tests. Likewise, the timings of two, five and 10 seconds were used to develop the dyes, so as to minimise the number of variables involved. The timings were manually controlled using a stop watch.

The intensity control was then used to note the appearance of the dyes when they were developed as a group, by a range of lower intensities of current at two and five second intervals, to give a visual overview of their colour and fading pattern.

The dyes used are illustrated at the beginning of each written section. Selected photographs illustrate the relevant points from tests, with the remainder set out in sketch books.

7.2.1 Solid colours developed by whole array

The Reversacol dyes used for testing were:



In Section 5.7.2 the dyes were developed by single LEDs. Developing them with the whole array would show how the dyes appear when developed by a platform of LEDs.

Printing:

Samples the size of the array (5cm x 5cm) were printed with each of the dyes.

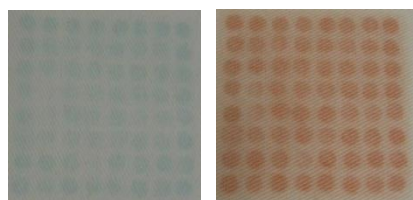
Observations:

The array was programmed to alternate between all of the LEDs being switched on and then switched off. The samples were developed for 10 seconds. The following observations were made:

- appearance of the colours of the dyes
- how much the colour surrounding each dot had developed

Results and Discussion:

The development of each dye showed 64 coloured dots arranged in a square, covering the surface area evenly with their circular shape. The spacing between each of the dots was more regular than would be created with the Impressionist painters' pointillist technique.



(a) 'Aqua Green' (b) 'Flame'

Fig. 7.1 Dyes developed by small array

'Oxford Blue' appeared very pale, fading very quickly, however it may be able to be used fleetingly. 'Aqua Green' (Fig. 7.1.a) and 'Plum Red', as faster fading dyes, noticeably began to recede immediately the light source was turned off. The remainder of the dyes stayed visible for longer, also in keeping with their fading speeds.

The fading of the dyes within each group was not completely uniform giving the surface print/image a more painterly, less computerised and technical overall appearance. This may have been due to inconsistent strength of light being emitted from the LEDs, as discussed in Section 5.7.2.3. ‘Midnight Grey’, ‘Volcanic Grey’, ‘Flame’ (Fig. 7.1.b) and ‘Corn Yellow’ developed peripheral colour between each of the developed dots, further softening the overall effect.

The size of these coloured dots and the depth of the shade of the developed colours will influence the scale of an overall design.

7.2.2 Daub motif developed by whole array

The Reversacol dyes used for testing were:



Although it was noted in Section 5.4.2 that when using only square shapes colour interactions were observed more easily, developing a daub motif with the LEDs would show how, for example, a mark reminiscent of one made by a paint brush would appear when made up by small dots of colour. Overlapping the dyes would allow for colour mixing by printing and it would also show how three colours within a design would appear when developed by the group of LEDs.

Printing:

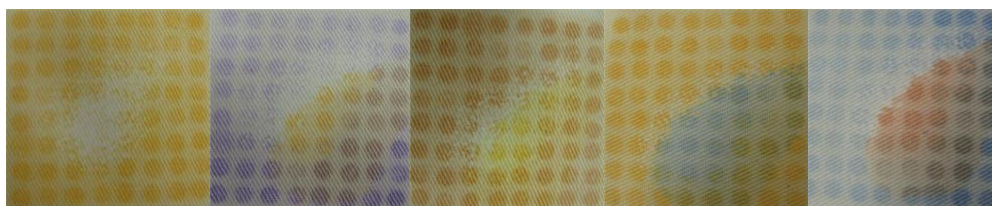
The design was made to fit the size of the small array. The background was printed using the first colour, leaving the daub area blank. Using the second colour, the daub was printed with some overlap onto the background colour. The following five contrasting colour combinations were used: ‘Flame’ and ‘Corn Yellow’, ‘Claret’ and ‘Corn Yellow’, ‘Corn Yellow’ and ‘Oxford Blue’, ‘Corn Yellow’ and ‘Palatinate Purple’, and ‘Palatinate Purple’ and ‘Flame’, anticipating the combined colours that would develop, i.e., orange, green and purple from dyes similar to the primary colours of red, yellow and blue. The combinations of colours also represented a cross-section of fading speeds.

Observations:

The light pattern from Section 7.2.1 was used. The samples were developed for 10 seconds. The following observations were made:

- colour development
- combined colours
- motif development
- fading

Results and Discussion:



(a) 'Corn Yellow' and 'Oxford Blue' (b) 'Claret' and 'Corn Yellow' (c) 'Flame' and 'Corn Yellow' (d) 'Corn Yellow' and 'Palatinate Purple' (e) 'Palatinate Purple' and 'Flame'

Fig. 7.2 Daub motif printed in different colours and developed by small array

Each sample was photographed immediately it was removed from under the array cover. The developed colours of 'Corn Yellow', 'Claret', 'Flame' and 'Palatinate Purple' can be clearly seen in Figure 7.2. The fading and the lightly coloured spaces between the dots would have decreased the overall appearance of the intensity of the dyes.

Although the results of the previous test showed that 'Oxford Blue' developed only very lightly, it was used in this test to observe its appearance when developed beside another dye. Although the dots made by the LEDs were not visible, there was a hint of the pale blue colour on the substrate (Fig. 7.2.a). The 'Flame' dye appeared orange when placed beside 'Corn Yellow' (Fig. 7.2.c) and red when placed beside 'Palatinate Purple' (Fig. 7.2.e).

The combinations of 'Claret' and 'Corn Yellow' (Fig. 7.2.b) and 'Palatinate Purple' and 'Flame' (Fig. 7.2.e) each developed into a shade of brown, 'Corn Yellow' and 'Palatinate Purple' developed into a shade of green (Fig. 7.2.d) and 'Flame' and 'Corn Yellow' combined to give a slightly darker shade of orange to the 'Flame' dye (Fig. 7.2.c), as anticipated. This shows that developing dyes that have been combined by printing, with LEDs, produces the expected resulting colours.

The shape of the daub mark was recognisable, illustrating that the dots could be used to build up a picture just as with mosaic tiles or the pointillists' technique, although consideration would need to be given to the design created so that it had the required clarity. When observing the pictures in Figure 7.2 as a group, my eye was drawn from one motif to the other reinforcing that the scale of any configuration of dots would need to be considered so as to create a picture that was proportionately more balanced and harmonious.

As each print faded, its recognisability varied, depending upon the fading speeds of the two dyes used.

It was noted that the illuminated LEDs shone brightly as they developed the dyes. This effect will be observed further in forthcoming tests.

7.2.3 Sketching of designs

As the LEDs on the array were arranged in a grid, various means for setting out the pattern plans were considered and trialled. For example, graph paper was enlarged on a photocopier to the size that the developed dots appeared on the fabric, and the outline of the LEDs was also traced onto tracing paper. However, it was decided that at this stage of the project, the size of the patterns being used was quite small so sketching them, as illustrated in the tests, proved sufficient. As the size of the designs increases, this method may need to be re-examined.

7.2.4 Solid colours developed by square light pattern

The Reversacol dyes used for testing were:



To achieve the aim of visual narration, it did not necessarily follow that the light source would be used to develop a motif that was printed in one place on the substrate and then, as that faded, develop another motif elsewhere. The light source may be used to develop the dyes within different parts of a larger design, both concurrently and consecutively.

The previous test showed three colours being developed at the same time and highlighted that the LEDs shone brightly as they developed the dyes. The dyes then began to fade at the same time when the LEDs were switched off. These results raised the question – how would a combination of several factors, i.e., the dyes being developed at different times, the brightly shining LEDs and the dyes commencing to fade at different times appear together on the substrate? Also, how would these factors be coordinated? As a starting point, a simple sequence of alternating square blocks of LEDs was used to develop individual dyes (Fig. 7.3). This would illustrate what would be seen by the viewer when a block of colour in one section faded, whilst another was simultaneously being developed. The combination of the light source and the developing dyes would also be observed.

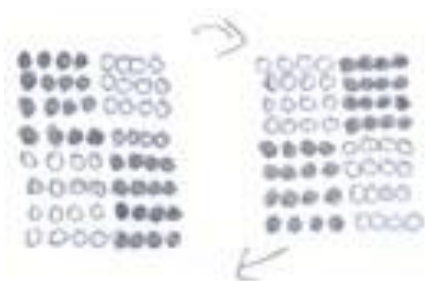


Fig. 7.3 Pencil drawing of light patterns

Samples:

Selected samples, covering the range of fading times, from Section 7.2.1 were used.

Observations:

The first set of square blocks of lights was switched on for 10 seconds then switched off. After a five second interval the second block of lights then developed the dyes for ten seconds. The five second interval was to allow the first square of developed dye to fade, to a greater or lesser degree, depending upon their fading speed, before the second square was developed. The following observations were made:

- the interplay of lights and developing dyes
- fading

Results and Discussion:

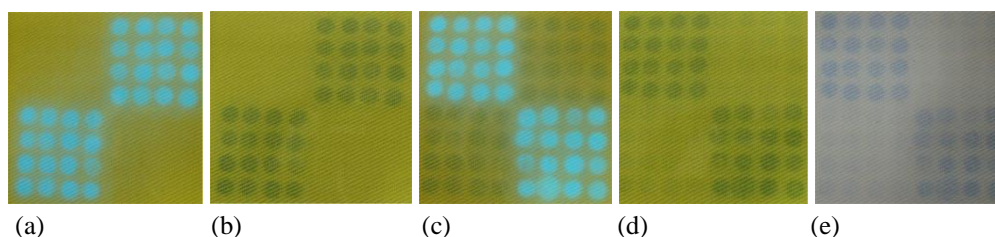


Fig. 7.4 'Palatinate Purple' dye developed by square light pattern on small array

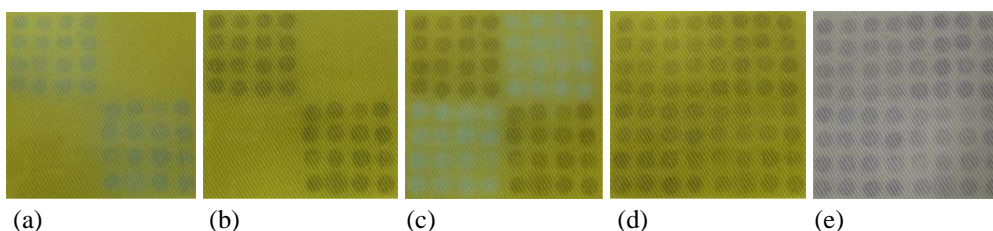


Fig. 7.5 'Midnight Grey' dye developed by square light pattern on small array

The effects of the different fading speeds of the individual dyes were clearly visible. For example, the first section of 'Palatinate Purple' to be developed (Figs. 7.4.a and 7.4.b) disappeared quickly from view (Figs. 7.4.c, 7.4.d and 7.4.e), whilst the first section of 'Midnight Grey' to be developed (Figs. 7.5.a and 7.5.b), as a slower fading dye, was still visible on the substrate (Figs. 7.5.c, 7.5.d and 7.5.e) after the second section of dye had been developed. These results also indicated that if a part of a design was developed by a light pattern that was in the same formation as the part of the design to be developed, the design, although moving as it faded back into the substrate, would still be somewhat stationary.

The lights of the LEDs were clearly visible, at times overshadowing the already developed dyes (Fig. 7.4.c). The combination of the light from the LEDs with the colours being developed is also clearly illustrated in both Figures 7.4 and 7.5. The colour created by this combination varied, depending upon the length of time the LEDs had been developing the dye.

The photographs in this set of tests, combined with those in Figure 7.2, illustrated, at this stage of the project, how the dyes may appear when developed together within a larger design.

Just as the yellow colour of the Perspex affects the colours of the dyes that we see, it also affects the combined colour of the developing lights and dyes. Although it is intended that clear Perspex will ultimately be used for this project, different colours of Perspex would also give different resulting shades of colour. These may create the desired effects for some end users.

7.2.5 *Daub motif developed by square light pattern*

The Reversacol dyes used for testing were:



Based on the results in Section 7.2.4, it was decided to develop the printed daub motifs, each containing two or three colours that fade at different rates, with the same light pattern as in Section 7.2.4, that is, one that didn't correspond with the motif, to observe the effects created.

Samples:

The printed samples from Section 7.2.2 were used.

Observations:

The dyes were developed for the same time intervals as those in Section 7.2.4. The following observations were made:

- the interplay of lights and developing dyes
- fading

Results and Discussion:

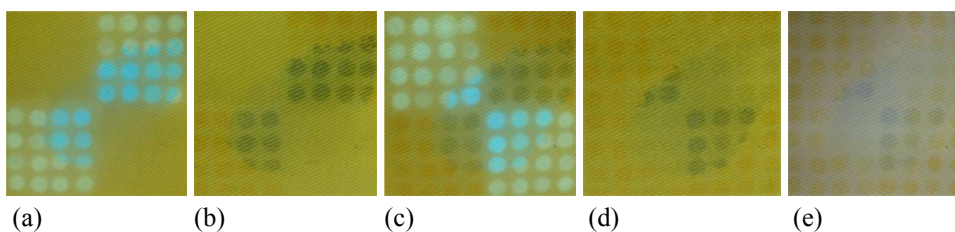


Fig. 7.6 'Corn Yellow' and 'Palatinate Purple' dyes in daub motif developed by square light pattern on small array

This exercise effectively illustrated how the order of development, the light pattern not corresponding with the printed design and the fading speed of the dyes affected the recognisability of the daub motif and can be seen by comparing Figure 7.6.e with Figure 7.2.d.

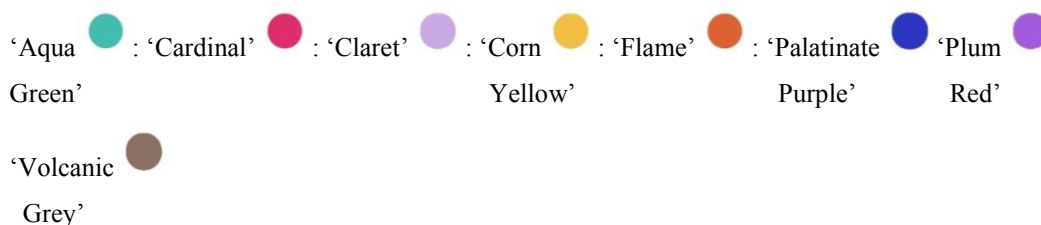
It was noted that the colour created by the combination of the dye being developed and the LEDs developing it also depended upon the strength of the colour of the dye. For example, 'Palatinate Purple' is a strong colour of dye and when it is being developed by the light source the colour we can see is bright light blue (Fig. 7.6.a). When the LEDs are developing 'Corn Yellow' the dots appear white (Fig. 7.6.c).

The designs created by developing the dyes with the LEDs may need to contain minimal detail to create sufficient impact. This may help to create a balance between the colours that are visible when the LEDs are developing the dyes and those that have

been developed and are then fading. This will be taken into consideration when planning designs.

7.2.6 *Extruded dyes developed by square light pattern*

The Reversacol dyes used for testing were:



As shown in Section 5.6.2, the extruded dyes developed to a stronger intensity and, in some cases, in different hues, than when printed. They were also shown to fade at different speeds from the printed dyes. Their appearance when developed by a group of LEDs, and as they faded when developed at different times, needed to be observed. Therefore, the light pattern as in Figure 7.3 was used.

Samples:

The polypropylene samples from Section 5.7.2.6 were used.

Observations:

The time intervals used in Section 7.2.4 were used to develop the dyes. The following observations were made:

- interplay of lights and developing dyes
- fading

Results and Discussion:

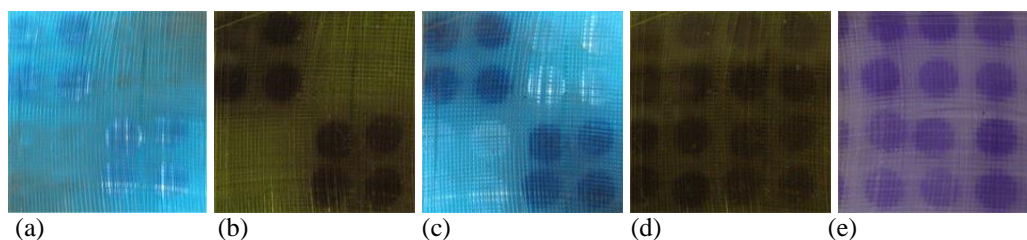


Fig. 7.7 Extruded 'Palatinate Purple' dye developed by square light pattern on small array

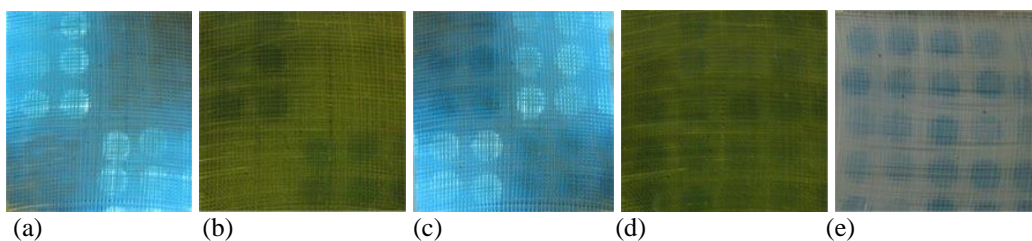


Fig. 7.8 Extruded 'Aqua Green' dye developed by square light pattern on small array

When the LEDs were illuminated, the colours of the developing dyes were able to be observed even though the Perspex was yellow, perhaps due to the transparency of the polypropylene and the effect produced by the light shining through it. The dye colour was either evident (Fig. 7.7.c) or not very noticeable (Fig. 7.8.c). However, when the light source was turned off (Figs. 7.7.b and 7.7.d, Figs. 7.8.b and 7.8.d) the colour of the polypropylene was ill-defined, affecting the practicality of using the dyes in this way. This was because the transparent polypropylene was placed immediately above the LEDs. Placing a backing substrate behind the polypropylene may resolve this problem and could be explored in future work. When the samples were placed on white paper their colour was clearly visible (Figs. 7.7.e and 7.8.e). Stitching the monofilament onto the substrate of the printed dyes would provide an alternative way of using the dyes in this form, however the extent to which they then developed would need to be ascertained. Although it was decided not to continue using the extruded dyes in this project, exploring their use in the ways mentioned above would be an interesting area of future work.

7.2.7 *Solid colours developed by squares and lines*

The Reversacol dyes used for testing were:

'Aqua Green' : 'Cardinal' : 'Flame' : 'Midnight Grey' : 'Plum Red'

Simple square light patterns showed the development and fading of both individual dyes and a combination of dyes, as shown in Sections 7.2.4 and 7.2.5. A slightly more complex light pattern developing an individual dye would increase the complexity of what was seen on the substrate. Therefore, the array was programmed as in Figure 7.9.

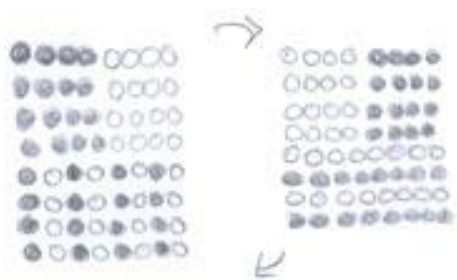


Fig. 7.9 Sketch of light pattern sequence

Samples:

Selected printed samples from Section 7.2.1 were used. The above dyes were chosen because of their varying hues and differences in fade times.

Observations:

Having noted the effects of the fading speeds of the dyes in Section 7.2.4, the patterns were changed from one to the other at five second intervals. The following observations were made:

- the interplay of lights and developing dyes
- fading

Results and Discussion:

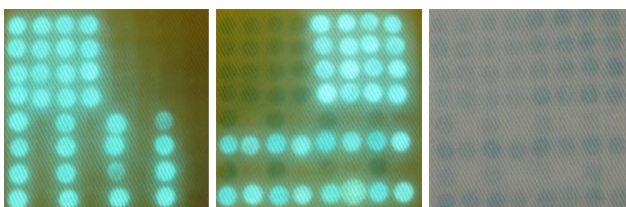


Fig. 7.10 'Aqua Green' dye developed by squares and lines on small array

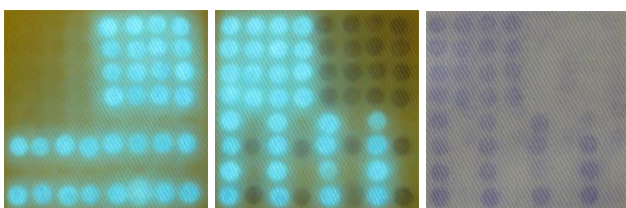


Fig. 7.11 'Plum Red' dye developed by squares and lines on small array

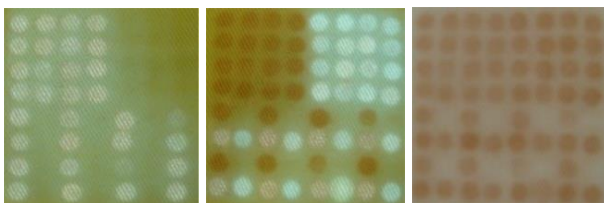


Fig. 7.12 'Flame' dye developed by squares and lines on small array

By comparison with the previous tests, the light source seemed to appear even more dominant in this sequence of patterns, as can be seen in Figures 7.10 and 7.11, with the combination of lights and developed dyes creating a busy image. When the LEDs were brightly visible in each step of the sequence, the surface area over which they developed the dyes appeared to be more than the half of the substrate that they actually covered. The more subdued effect of the lights, as illustrated in Figure 7.12, may be more desirable as they complement the printed dyes rather than overshadow them.

Again, the fading of the dyes was dependent on their fading speed, with the faster fading dyes disappearing quickly from the substrate. This left less dye visible once the LEDs were not illuminated, as shown with the ‘Plum Red’ dye in Figure 7.11.

These observations have reinforced the need to find a balance between using simple patterns and more complex ones, whilst also balancing the amount of time used to develop the dyes with their fading speeds. Additionally, the effects of the combination of the light source and these dyes may not need to be viewed as a hindrance. Certainly the visibility of the light source creates a more complex effect than when the dyes are developed by sunlight however the aim will be to utilise the lights to enhance a design.

7.2.8 Solid colours developed by single column

The Reversacol dyes used for testing were:



The split screen effect, used in French Impressionist films (as discussed in Chapter 3), enabled a change from one screen image to another. Therefore, the progressive development of the dyes by a single column of light that moved from left to right, as shown in Figure 7.13, was trialled. The intention was to create a sense of forward movement.

As explained in Section 3.3.3, the technique of rhythmic editing assisted in the creation of emotions and mood, drama and physical action. Therefore, the lights were also used to develop columns of dye at random intervals, whilst still moving from left to right, to note the effect that their development, either slowly or in quick succession, had on the marks made on the substrate and their subsequent fading.

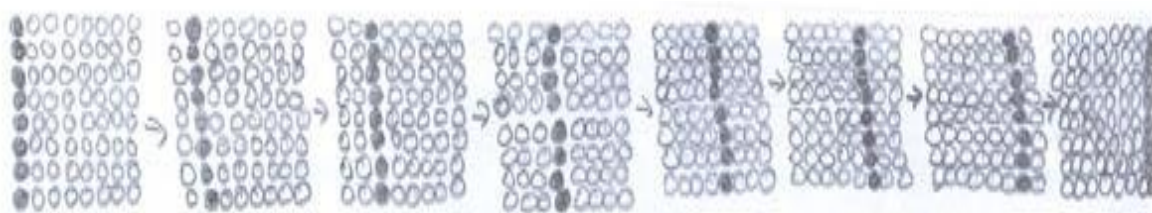


Fig. 7.13 Sketch of light pattern sequence

Samples:

Selected printed samples from Section 7.2.1 were used. The above dyes were chosen because of their varying hues and differences in fade times.

Observations:

The single column of light was used to develop the dyes as they progressed from left to right at two, five and 10 second intervals. It was also used to develop the dyes at random intervals. The following observations were made:

- the appearance of the dyes as they developed and faded in columns at regular intervals
- the appearance of the dyes as they developed and faded at irregular intervals

Results and Discussion:

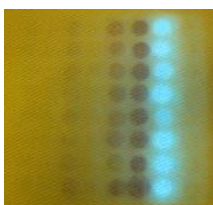


Fig. 7.14 'Claret' dye developed by single light column on small array

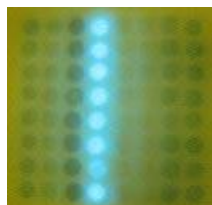


Fig. 7.15 'Palatinate Purple' dye developed by single light column on small array

Figure 7.14 shows the fast fading 'Claret' dye being developed by a column of light, at regular two second intervals. As it is fast fading, the amount of colour remaining visible was much less than for the slower fading 'Flame' dye. The effects made by this pattern would also apply if it was used to develop the dyes in reverse order, i.e., from the right side of the array to the left, or from the top of the array to the bottom and vice versa, also emulating the split screen effect or the iris technique.

Changing from regular to irregular time intervals gave a glimpse of how varying the rhythm of the dyes' development would affect how the dye appeared on the substrate. The slightly slower fading 'Palatinate Purple' dye illustrates this in Figure 7.15, showing how the amount of surface area covered with developed colour is affected by

varying the development of the dyes in this way and will need to be considered within a larger design. Overall, it encouraged the nurturing of this aspect of using the dyes and the creation of rhythmic movement.

The blocks of colour fading at different speeds in Section 7.2.4 had more presence on the substrate than these single columns. Additionally, the smaller area of substrate covered by the columns of developed dye was overshadowed by the lights of each column of LEDs. However, the fine line of dots was inspiring to watch. Seeing their simple progressive development, in sequence from left to right as columns of dye slowly faded behind new ones being developed, as though each column of dye was moving forwards, illustrated that there was potential for controlling the dyes to create an image akin to a moving picture.

7.2.9 Pattern making

When looking at the photographs of the fading dyes, whilst doing the observations for Sections 7.2.2 and 7.2.4, thoughts arose as to how a design made up of the dots of colour would appear. At this stage it was decided to print out copies of some of the photographs that were taken and experiment with their placement, as if they were mosaic tiles, and build a larger image.

The prints were moved around on paper and placed in various arrangements. By rotating them, different patterns could be made using the same photo and this could be repeated to make a larger pattern. The effect created by variations in the depth of shade of colour could be seen. The definition, and therefore recognition, of the patterns varied depending upon how much colour had faded and the fading speed of the dye. When photographs of the slower fading dyes that had been developed by the light formation of squares and lines were placed side by side in a simple repeat pattern, a larger pattern was able to be clearly seen. However, the result was distinctly different when the same arrangement was made with the faster fading dyes, as parts of the pattern were not visible where the dyes had faded. Although each small photo represents only a captured moment, these exercises encouraged reflection on the design process in general and how to work with these dyes.

Patterns reminiscent of the shapes and colours seen through a kaleidoscope were also made (Fig. 7.16). These images brought to mind the shapes and movements created by

the stylistic techniques of the French Impressionist films that were chosen as a way of initially guiding the development of the dyes and their colours. These results illustrate that this may be an effective way of combining those techniques with the dyes. Although knowledge of how the dyes appear as they fade helps envisage how this may occur, the building of kaleidoscopic, or similar, imagery would need to be explored in practice.

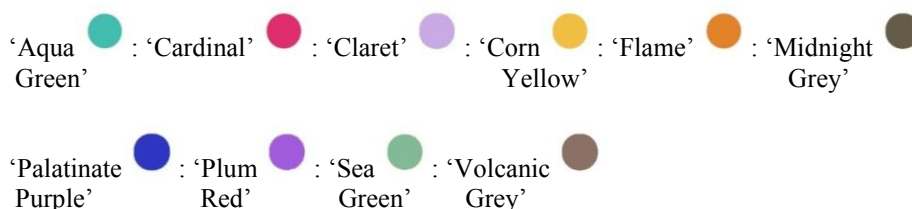


Fig. 7.16 An example of a pattern made using paper prints of photographs of developed photochromic dye

Being able to stand back and see the patterns made by the dots was helpful. The same process could also be followed using Photoshop.

7.2.10 *Fading of solid colours*

The Reversacol dyes used for testing were:



There was now a clear Perspex cover on the small array enabling the true colour of each of the dyes to be seen. To gain a visual overview of the presence that they would have on the substrate, either as a motif or as the background colour of a larger design, each dye was developed by the whole array and observed as it faded at 10 second intervals. The amount of colour that could be seen on the substrate, at particular periods of time, could then be anticipated.

Although a means of filming the dyes (that was concurrently being explored as described in Section 6.3.1) had by now been established, it was decided to continue to use photography and to mount the images, as in Section 5.4.4. This had proven to be an

easily accessible way of seeing the fading pattern of all of the dyes as they were set out together and would be useful for design planning.

Samples:

The printed samples from Section 7.2.1 were used. ‘Oxford Blue’ was not included as it developed only fleetingly in Section 7.2.1.

Observations:

The array was programmed to alternate between all of the LEDs being switched on and then switched off. The samples were developed for 10 seconds. The lights of the array were turned off and the dyes photographed at 10 second intervals. The following observations were made:

- colour of the dyes as they faded

Results and Discussion:

As in all previous tests, these dyes were developed at a current of 20mA. The amount of time they remained visible on the substrate was comparable with the measurements of the dyes when they were developed by the individual LEDs in Section 5.7.2.2.

The photographs show that the majority of the colour of the ‘Plum Red’ and ‘Aqua Green’ dyes had faded within 10 seconds and the ‘Claret’ and ‘Palatinate Purple’ dyes within 20 seconds. ‘Sea Green’, a dye that sits in the middle of the fading spectrum, left minimal colour on the substrate after 40 seconds (Fig. 7.17.e).



(a) Immediately (b) 10 seconds (c) 20 seconds (d) 30 seconds (e) 40 seconds

Fig. 7.17 ‘Sea Green’ dye developed by small array and fading at 10 second intervals

‘Corn Yellow’, ‘Cardinal’, ‘Midnight Grey’ and ‘Volcanic Grey’ showed minimal colour after approximately one minute. ‘Flame’, as the slowest fading dye, still showed some colour on the substrate after two and a half minutes.

These images give an indication of the approximate intensity of each colour that would still be visible on the substrate, at a particular time during the period in which they were

fading, if they were developed using the current of 20mA. They also show that there would still be some colour visible on the substrate for approximately two and a half minutes, if using the slower fading 'Flame' dye, thereby helping to establish a parameter within which the construction of a design could be planned. It was also beneficial to see how the dot mark appeared as it progressively faded as part of a group, giving an indication of what would be seen within a larger image.

The rows of fading colours, observed together, hinted that the faster fading brighter dyes, with their green and purple hues, may need to be used as short bursts of colour in amongst the slower fading yellow, orange and grey dyes. Whether this works effectively will be determined by the designs developed. Designing will need to accommodate, as well as utilise, the varying fade times of the dyes.

7.2.11 Solid colours developed by different strengths of current

The Reversacol dyes used for testing were:



As discussed in Chapter 4, artists and designers vary the depth of colour of the medium they are using to create a particular mood or effect within paintings or other design work. In Section 5.7.2.2, the currents of 1, 2, 5, 10, 15 and 20mA developed the dyes for two, five and 10 seconds and showed that by varying the strength of current sent to the LEDs, the strength of the colour of developed photochromic dye could also be varied. Thus far, the current of 20mA had been used within tests. However, as it was not anticipated that the dyes would only be developed by LEDs at this strength, the currents of 5, 10 and 15mA were used. As the development times of the dyes would also vary, the shorter time of five seconds was chosen as, based on the results of Section 7.2.8, the dyes would be developed, within a design, at varying times, to explore the creation of rhythmic effects.

Samples:

As time did not permit testing of all of the dyes, only selected colours were observed. 'Claret', 'Sea Green' and 'Volcanic Grey' printed samples from Section 7.2.1 were chosen as they represented a cross-section of colour strengths and fading speeds.

Observations:

Using the intensity dial, the array was set at a current of approximately 5mA. The dyes were developed for a period of five seconds. The lights of the array were turned off and the dyes photographed immediately and at approximately five second intervals as they faded. The observations were repeated with the array set at both 10mA and 15mA. The following observations were made:

- colour intensity
- fading pattern of the dyes

Results and Discussion:

The gradual increase in colour strength of each dye, when developed by the different currents, could be clearly seen in the photographs. The gradual fading of each dye was relative to the intensity of current that had been applied to the LEDs and the amount of time they were developed. These results show how the array could be used to effectively develop the dyes to varying depths of shade, potentially enabling different moods or atmospheres to be created within designs. Again, seeing the dots of dye as a group was helpful for visualising how the variations of colour would appear.

7.2.12 Fading of dyes mixed by printing

The Reversacol dyes used for testing were:



In Section 7.2.2, the developed colours of the dyes that had been mixed by printing could be seen. As it was anticipated that mixed dyes would be used, and to build on the visual knowledge of the dyes' colour palette, it was decided to develop each combination of mixed dyes and observe their fading. Again, the shorter time of five seconds was used.

As there were so many colour combinations, even when using two dyes, it was decided to observe the pairs as they faded at 30 second intervals. Although it may seem to be a long interval, these were combinations of faster fading and slower fading dyes and an

overview of how much colour would remain visible on the substrate would be able to be seen.

Printing:

Samples, each the size of the array (5cm x 5cm), were printed with the dye combinations.

Observations:

The intensity dial was set at 20mA. The samples were developed for five seconds. The lights of the array were turned off and the dyes photographed immediately and at 30 second intervals thereafter. The following observations were made:

- colour of the combined dyes as they progressively faded





Results and Discussion:

Although not as clear as when developed by sunlight the colours created by the combined dyes, when developed by the array, were still easily recognisable. With the gradual disappearance of the faster fading dye in each pair, the depth of colour of the slower fading dye was able to be seen. As in Section 7.2.10, after approximately two minutes, there was only minimal colour from the slower fading dyes on the substrate. The photographs will be a useful reference when designing.

It was noted that when the 'Cardinal' dye was mixed with 'Corn Yellow' and 'Flame' it stained the substrate yellow, giving another example of the unpredictability, and perhaps instability, of this particular dye. Its use will need to be considered.

7.2.13 Mixed colours developed by different strengths of current

The Reversacol dyes used for testing were:

'Flame'  : 'Palatinate  : 'Sea  : 'Volcanic 
Purple' Green' Grey'

Sketching the stylistic techniques and analysing the photographs of clouds highlighted that it would be useful to note the extent of the variation of the colour that would be visible as the combined dyes faded, when they had been developed by different currents and for a different amount of time.

Again, as there were so many colour combinations and as knowledge of the way they perform had accumulated, it was decided to develop only two pairs of dyes. These pairings were selected based on the dyes' colours and fading times. The photographs taken for the observations in Section 5.4.4 were useful when deciding which pairs of dyes to use. The dyes were developed for two seconds because the concurrent observations that were noted as the dyes were being filmed showed that when they were developed for this amount of time interesting colour interactions were observed.

Samples:

The combination of 'Flame' and 'Palatinate Purple' was chosen as these colours are placed at opposite sides of the colour wheel. 'Flame' is the slowest fading dye and 'Palatinate Purple' is placed closer to the faster fading dyes. The combination of 'Sea Green' and 'Volcanic Grey' was chosen as both of these colours are placed towards the middle of the dyes' fading order and they are also unrelated on the colour wheel. The printed samples from Section 7.2.12 were used.

Observations:

The intensity dial was set at 15mA. The samples were developed for two seconds. The lights of the array were turned off and the dyes photographed immediately and at five second intervals thereafter. The same procedure was followed after setting the array at 20mA. The following observations were made:

- colour of the combined dyes as they progressively faded

Results and Discussion:

There were very subtle differences in the colour intensities of the dyes when they were developed by the 15mA and 20mA currents. Although the amount of time for development was only two seconds, the effect of 'Palatinate Purple' and 'Sea Green' within their respective combinations could be seen, indicating that the different intensities of current and different time frames could be subtly used. These results were compared with the photographs from Section 5.8.2. It was noted that there is more of a marked difference between the intensity of a colour developed at a lower current than that developed at a higher current and this will be taken into consideration when choosing the intensity at which to develop the dyes.

7.2.14 Summary

In this series of tests, as the dyes were developed on the small array in a range of scenarios, the effect that their movement created was highlighted, emphasising the deviation in their behaviour from that of traditional dyes. Planned from a design perspective, the tests provided an opportunity to address the question of combining the light source with the placement of the dyes that can only be resolved by putting these two elements together in practice. Within this question, secondary questions were raised regarding the development, coordination and fading times of the dyes. The results of observations have shown that:

- the dots made by the LEDs could be used to build up a picture however the scale of any configuration would need to be considered to give the design the appropriate clarity.
- the ability to alter the current that develops the dyes, and the amount of time that each dye is developed, is considered beneficial as it provides different shades of colour that will be able to be used for addressing the project question. Mixing by printing also adds different shades of colour and additional fade back effects into the equation.
- the amount of time used to develop the dyes will need to be considered from two angles - how long the resulting developed colours are to remain on the substrate and the corresponding presence of the lights of the LEDs - as a state of balance needs to be found between these two elements.

Additionally,

- the colours that the lights and the dyes appear together depends upon the strength of the colour of the dyes and the length of time over which they are developed.
- lowering the current and developing the dyes for shorter periods decreases the dyes' colour strength and the amount of time they are visible on the substrate, whilst lessening the amount of time the light source can be seen.
- blocks of dots fading at different speeds have more presence on the substrate than single columns of dots. However,
 - the size of the area of colour being developed determines the size of the area over which the light from the LEDs will also be visible.

- designs containing minimal detail may create sufficient impact of colour and be a way of finding a balance between using simple light patterns and more complex ones.
- as well as their vertical development and fading being able to create the illusion of depth, and their lateral development and subsequent fading pattern creating a sense of sideways movement, varying the rhythm of these actions has been shown to create a sense of tension that could be effective for changing the sense of atmosphere or mood created.

As more variables were added to the tests, what was seen became more complex. As more tests were carried out, the effects created by the difference between the fast fading and the slow fading dyes visually reinforced that the surface of the substrate will be covered for different periods of time with colour that will always be fading.

In Section 7.2.5, the daub motif was less recognisable when developed by a light pattern (in the shape of squares) that did not correspond with its printed design, illustrating the importance of the formation of the light pattern, as it has a presence that is then replaced by the fading dyes. Although their staggered fading order meant that part of the motif was visible for longer whilst part of it faded away more quickly, the effect created by the two disparate shapes, that is, the one created by the lights and the one created by the developed printed dyes, will need to be carefully considered. However, combining the placement of both of these elements, if done skilfully, may enable two very different images to be created by dyes that, although they move as they fade, are essentially anchored to the substrate.

Watching the colours move helps to formulate ideas about ways the dyes could best be placed together, just as looking at development work in any static medium enables what has already been constructed to be reflected upon, and built on. A suitable means for recording the dyes has begun to be explored and is explained in the section on filming and recording, Section 7.3.

The tests carried out on the small array have been simple using the array's capabilities however only so much could be ascertained working at this scale. Although the tests have been beneficial for understanding the way the dyes appear when using this form of

light source, an array that provides a larger surface area for developing the dyes and observing the effects created, whilst providing more ease and flexibility with the way its functions are used, is needed. Therefore, a larger array will be built so that the project work can develop further.

7.3 Filming and Viewing Dye Development

To be able to work more effectively with this ‘invisible’ medium, it was necessary to establish a means for recording the dyes and a platform upon which the work could be easily viewed.

7.3.1 *Filming the dyes*

Whilst carrying out the observations in Section 7.2, a small digital camera was used to film several of the printed samples as they developed in sunlight. This recording enabled repeated viewing of the dyes as they developed and the colour change, as it increased in intensity, was able to be watched easily. This exercise demonstrated that the medium of film would enable the dyes to be viewed when being developed by artificial UV light in a similar way to how they are observed when being developed by sunlight. The printed ‘Palatinate Purple’ and ‘Flame’ daub motif was also filmed as it was being developed by a column of lights, moving from left to right as described in Section 7.2.8. Watching the playback of this recording was very inspiring. It was my first experience of seeing the development of an actual design, albeit simple, by a group of LEDs whilst I wasn’t involved with either pressing the button on the array or taking photographs. This gave me the opportunity to see a design developing as an observer, thereby shifting my perspective. That shift was important as I was also able to see the work as a viewer, not only as the maker, an important standpoint to consider when working on this project. As the capacity of this camera to record was limited, photographs continued to be used to document the actions of the dyes until a suitable means of filming was found.

As a handheld video camera proved unsatisfactory, a larger-sized digital camera, with a greater recording capacity than the one used previously, was trialled. Four solid colour samples were also filmed as they were being developed by the column of lights. Although no new observations from those noted were made, watching the replay of the recordings, as the dyes were being developed by the small array, did illustrate how the movement of the colours would appear if the LEDs were being controlled by a computer programmable array.

As the French Impressionist film techniques were concurrently being analysed, it became apparent that the single column of lights, mimicking the iris technique, could be used in diverse ways to develop the dyes. It was therefore decided to use this light configuration to develop both solid colours and the multi-coloured dot motif to observe the resulting effects.

7.3.1.1 Solid colours developed by single column at two, five and 10 second intervals

The Reversacol dyes used for testing were:



As clear museum-grade Perspex now covered the array and an appropriate means of filming had been established, the capacity of the dyes to emulate the split screen effect, discussed and photographed in Section 7.2.8, could now be more seamlessly observed. As the dyes were developed at each of 2, 5 and 10 seconds in Section 5.7.2.2, these timings would continue to be used in this set of observations to provide a baseline for reference.

Samples:

The samples from Section 7.2.1 were used.

Observations:

The column of LEDS was moved from left to right at each of the time frames, to develop each dye, and filmed. The following observations were made:

- the appearance of the dyes when they were developed by the LEDs at each of the time frames
- the appearance of the fading of the columns

Results and Discussion:

The filming enabled comparisons to be made between the numbers of columns of each dye that remained visible on the substrate when the light source had reached the end of the array. Each of the videos was observed separately. These observations were recorded in Tables 7.1-7.3.

‘Oxford Blue’ remained barely visible when developed at each time interval and so was not included in the tables.

The dyes were arranged in the first column in Table 7.1 according to their speed of fading in relation to one another. The following columns show the colour, colour intensity and the number of columns of each dye, or part thereof, remaining visible on the substrate when the column reached the right hand side of the array. The order of the dyes in the first column in Table 7.1 was also followed in Tables 7.2 and 7.3, so that it was easier to see any differences in the way the dyes responded when they were developed for longer periods of time.

The fading order varied slightly from that stated in Section 5.7.2.3, however the dyes were not being viewed on the same screen and this may account for any differences noted.

Fading speed	Colour	Intensity	Columns developed	Dye
fast	green	pale	0.5	‘Aqua Green’
fast	purple	medium	1.5	‘Plum Red’
fast	purple	bright	3	‘Claret’
fast	dark blue	bright	3	‘Palatinate Purple’
medium-slow	sea green	medium	7	‘Sea Green’
slow	yellow	bright	8	‘Corn Yellow’
slow	salmon	pale	7-8	‘Cardinal’
slow	grey	medium	7-8	‘Volcanic Grey’
slow	dark grey	bright	8	‘Midnight Grey’
slow	burnt orange	bright	8	‘Flame’

Table 7.1 Dyes developed at two second intervals

Fading speed	Colour	Intensity	Columns developed	Dye
fast	green	pale	0.5	‘Aqua Green’
fast	purple	stronger	1	‘Plum Red’
fast, slightly longer	purple	slightly brighter	1	‘Claret’
fast	dark blue	brighter	0.5	‘Palatinate Purple’
medium	sea green	slightly stronger	2.5	‘Sea Green’
slow	yellow	bright	7-8	‘Corn Yellow’
slow	salmon	medium	8	‘Cardinal’
slow	dark grey	slightly brighter	5	‘Midnight Grey’
slow	grey	sl stronger	8	‘Volcanic Grey’
slow	burnt orange	slightly brighter	8	‘Flame’

Table 7.2 Dyes developed at five second intervals

Fading speed	Colour	Intensity	Columns developed	Dye
fast	pale green	very pale	0	'Aqua Green'
fast	purple	stronger	1	'Plum Red'
slower	purple	slightly brighter	0	'Claret'
fast	dark blue	bright	0	'Palatinate Purple'
medium	sea green	slightly stronger	1-1.5	'Sea Green'
slow	yellow	slightly brighter	1.5-2	'Corn Yellow'
slightly slower	salmon	slightly stronger	4-5	'Cardinal'
slow	dark grey	slightly darker	3-3.5	'Midnight Grey'
slow	grey	slightly stronger	6-7	'Volcanic Grey'
slow	burnt orange	slightly brighter	5-6	'Flame'

Table 7.3 Dyes developed at 10 second intervals

The tables give useful information of how each dye fades as another column of that dye is being developed. For example, a fast fading dye such as 'Claret' appeared slightly brighter and to take slightly longer to fade when developed for five seconds than when developed for two seconds. This increased intensity of colour gave it more visual impact during the time it was visible, however the five seconds spent developing each column also meant there was more time for the previously developed columns of dye to fade. This occurred similarly with all of the dyes and moreso when they were developed for 10 seconds. Certainly, the dyes may not be developed in this columnar configuration, however the period of time each dye would remain on the substrate, and its subsequent depth of colour, after the light source had moved to another position, could be applied to any configuration and in any direction.

The spaces between the developed slower fading 'Midnight Grey' and 'Flame' dots were filled with a lighter shade of each of those colours at each of the time frames. The spaces between the developed 'Volcanic Grey' dots were pale grey only when that dye had been developed for 10 seconds.

As the dyes developed by the sideways moving light column faded, they appeared to have a more flowing sense of movement, with more lightness than they displayed when they were developed as a block and then faded as a block. In Section 7.2.4, as they faded vertically, the blocks of colour maintained a sense of being anchored to the substrate whereas this lateral development hinted at the more organic aspect to the dyes that they appeared to have in Section 5.4.2 when they were developed by sunlight. This

was an encouraging element to consider with regards to narrative, the sense of changing from one place to another.

7.3.1.2 Daub motif developed by single column at two, five and 10 second intervals

The Reversacol dyes used for testing were:



The dyes may be developed by a group or a line of LEDs, or by individual LEDs. Developing each print by a column of light, moving progressively from left to right, would show how the staggered fading of the colours would appear on the substrate when different parts of a design, and different colours, were being developed consecutively. It would also demonstrate whether the sense of forward movement created in Section 7.2.8 could be created when several dyes placed together were fading at different speeds.

Clearly, there are many colour combinations and placements in which the dyes could be arranged. However, to maintain a constant whilst observing the effects created when a multi-coloured design was developed for different periods of time, the simple daub motif samples from Section 7.2.2 were used.

Observations:

Each print was developed for intervals of two, five and 10 seconds and filmed. The following observations were made:

- the colour intensity of each print and the fading pattern observed when developed at each of the time frames
- the overall impression of the dyes developing for different time intervals and fading at different speeds

Results and Discussion:

At each time frame 'Oxford Blue' was only fleetingly visible, leaving the part of the motif where it was printed mainly uncoloured. Considering the results of this test and the results of Section 7.2.1, perhaps a solid block of light could be used to develop the 'Oxford Blue' dye in one instance and, at another time, a single column of lights would give a different effect, with the 'Oxford Blue' dye remaining uncoloured.

For the remainder of the motifs, the two second time frame was clearly the most effective as it enabled a gradation of colour, ranging from fully developed to nearly faded, to be seen on the substrate as though each motif was a passing image. However, the sense of forward movement, that was created when the light column developed the single colours, was affected by the dyes' different fading speeds and the strength of colour of the two dyes used. For example, the slower fading 'Corn Yellow' dye appeared anchored under the faster fading 'Claret' dye that seemed to move over the top of it, whilst the 'Corn Yellow' dye appeared to move over the faster fading 'Palatinate Purple' dye, giving a softer and lighter effect as the 'Palatinate Purple' faded back into the substrate. The 'Corn Yellow' and 'Flame' dyes, from the same end of the colour and fading spectrum, created a more balanced and harmonious effect, see video x.

Also at the two second interval, the 'Palatinate Purple' dye appeared to pass over the slower fading 'Flame' dye. However, at the five and ten second intervals, it had more time to fade, so the slower 'Flame' dye appeared to shift from being behind, to being in front of, the 'Palatinate Purple' dye. The effect of the combined colours was also most clearly seen at this time frame, the brightness of the column of lights did not intrude on the design and the movement of the column did not interfere visually with the overall effect of the developing and fading dyes.

Overall, the five second development time was less effective than the two second one, as a lot of the print had faded, visually illustrating the results gathered in Section 7.3.1.1. If one dye was fast fading and the other slow fading it resulted in only the slow fading dye remaining on the substrate and only part of the motif remaining visible. If both of the dyes were slow fading the motif was clearly seen as more dye colour remained.

At the 10 second development time the motif was even less apparent, as more of each dye had faded. At times, all of the dyes had faded and there was very little colour on the substrate. The lights started to become more noticeable when developing at this slower pace, especially when the difference in fading times of the dyes was greater, as there was not as much colour remaining.

Dye	Combined colour of LED and dye
‘Oxford Blue’	bright white
‘Claret’	white to bright blue
‘Corn Yellow’	white to pale salmon
‘Flame’	white to pale lilac
‘Palatinate Purple’	white to bright blue

Table 7.4 Combined colour of the light source and the dye

Table 7.4 shows the colours created by the combination of the lights and the dyes. The longer the lights developed the dyes, the brighter the resulting combination and the contrast that this created with colours that were already developed.

7.3.1.3 Daub motif developed by whole array at two, five and 10 seconds

After noting the appearance of each motif when it was developed by a column of lights in Section 7.3.1.2, it was decided to take a step back and observe each print being developed by the whole array at each of two, five and 10 seconds. The effects created by the different development times on the colours would be noted and compared with one another.

Observations:

Each print was developed for the time periods of two, five and 10 seconds and filmed. The following observations were made:

- the effect of the light source behind the dyes
- the strength of the developed colours
- the fading of these colours

Results and Discussion:

When developed by the whole array each motif was clearly visible and changed according to the development times and the corresponding fading times of the dyes used. Each motif was defined more clearly and had more presence when developed for five and 10 seconds because the colours had developed to a greater intensity. This also made the area where the dyes were overprinted more clearly noticeable. ‘Oxford Blue’ was clearly visible on the substrate for a few seconds when developed for 10 seconds.

Although the colour in the spaces to the periphery of each developed circle of dye was pale, it was of a stronger intensity than when the dyes were developed by the passing column of lights.

Developing the whole motif with the small array meant there was a large block of LEDs developing the dyes. The result was a very bright combination of lights and developing dyes and, although there was a gradual change to its colour, this block had an otherwise static presence for the period of time the dyes were being developed. The contrast between the different colours of the lights as they developed the dyes was, however, striking. The combined colour of light and dye changed the longer the dye was being developed, as set out in Table 7.5, thereby changing the way the motif was presented. For example, the ‘Corn Yellow’ dye appeared matt yellow when being developed beside the ‘Flame’ or ‘Claret’ dyes, and varying shades of salmon when being developed beside the ‘Oxford Blue’ or ‘Palatinate Purple’ dyes.

Daub colours	Dyes and lights 2 seconds	Dyes and lights 5 seconds	Dyes and lights 10 seconds
‘Corn Yellow’ and ‘Oxford Blue’	matt white bright white	pale salmon bright white	salmon bright white
‘Claret’ and ‘Corn Yellow’	bright blue matt yellow	bright blue matt yellow	bright blue matt yellow
‘Flame’ and ‘Corn Yellow’	white/pale pink bright white	white/lilac matt yellow	white/lilac matt yellow
‘Corn Yellow’ and ‘Palatinate Purple’	white light blue	pale salmon bright blue	salmon bright blue
‘Palatinate Purple’ and ‘Flame’	white/light blue pale pink	white/bright blue yellow	white/bright blue yellow

Table 7.5 The combined colour of the LED and the dye differed depending upon the placement of the dye.

In two areas, the combinations of mixed dyes and lights developed a noticeably different colour. After 10 seconds of development the combined area of ‘Flame’ and ‘Corn Yellow’ developed to a shade of dark salmon pink. After two, five and 10 seconds of development the combined area of ‘Flame’ and ‘Palatinate Purple’ developed to a shade of dark salmon pink.

When the LEDs were switched off, the lights disappeared and the colours of the dyes that were being developed were able to be seen. The colours of the dyes changed once again as they faded.

In this exercise, as in Section 7.3.1.2, it was also observed that as the ‘Palatinate Purple’ progressively faded, a change took place as the ‘Flame’ dye appeared to dominate the image with its colour. Both of these incidents, where a shift in the perceived prominence of a colour occurred, are important, particularly with regard to narrative - as the dyes fade, the balance of colour changes, thereby changing any image or design. Initially hinted at in Section 5.4.4 (when the dyes that had been mixed by printing were developed by sunlight and then observed fading), this effect, created by controlling the dyes’ movement with artificial UV light, encourages the potential of the dyes to create narrative effects. It also highlights the significance of placement and proportion of colour when creating designs with these dyes.

7.3.2 Platform for viewing videos

A platform was needed on which to place the videos of the dyes so they could be observed as a group, illustrating the concept of the dyes being developed by a larger-sized array. By placing filmed dye colours beside other filmed dye colours, the rhythm and pattern of their different times of development and different fading speeds would be able to be seen.

As a starting point, four videos, showing individual colours of dye being developed by columns of light, were placed in a table on a webpage, as explained in Section 6.3.2. The videos appeared on the screen randomly and each one started to play immediately. The light columns, constantly visible, appeared bright and dominated the screen. The videos were unable to be paused mid-play and would need to be cropped so that only the lights and dyes were in view. Although not ideal, this exercise did prove useful for initially showing a group of dyes developing and fading together on a screen, simulating the concept of dyes being developed on some parts of the substrate whilst in other areas they faded.

Mounting the videos from Sections 7.3.1.1-7.3.1.3 together in tables also proved unsuccessful, mainly because the playing speed of the videos had markedly slowed down. However, it was illustrated that the association of a particular fading speed with a particular dye would indicate that a certain area of a design would be ‘slow’ on the substrate and another area ‘fast’. This effect may be lessened by using the fading pattern created when one colour is printed on top of another, however this would add more colours to a design, and the subsequent additional movement of that colour

combination. Overall, these exercises illustrated the concept of a moving image and increasingly demonstrated that the number and formation of LEDs developing a dye, and the amount of time the dyes were being developed, alters the effects created. Ultimately, a multimedia software programme, Adobe Flash CS3 Professional, provided a platform in which the video files could be uploaded and subsequently viewed.

7.3.3 Summary

Within this section the dyes' colours and their fading patterns have been observed, both individually and as part of a multi-coloured print, in a range of scenarios, and developed by the LEDs at the time frames of two, five and 10 seconds, to provide a constant baseline from which an overview of their interactions and movements could be built.

Narrative effects:

The following ways of using the dyes, that show the potential for creating visual narrative, have been isolated:

- A sense of **forward movement** was created when developing individual dyes with a column of lights with the resulting sense of momentum dependent upon the fading speed of the dye and the time interval used to develop it.
- The most **recognisable transitory image** was created by developing the daub motif (multi-coloured) with a single column of light at the *two second* interval. It effectively enabled a graduation of colour, ranging from fully developed to nearly faded, to be seen. The importance of the colour, its strength, the placement and fading speed of the dyes, when developed in this way, was also highlighted:
 - the slower fading 'Corn Yellow' dye appeared anchored under the faster fading 'Claret' dye that seemed to move over the top.
 - the slower 'Corn Yellow' dye appeared to move over the faster fading 'Palatinate Purple', giving a softer and lighter effect as the 'Palatinate Purple' faded back into the substrate.
 - the slow fading 'Corn Yellow' and 'Flame' dyes, from the same end of the colour and fading spectrum, created a more balanced and harmonious effect.
 - the 'Palatinate Purple' dye appeared to pass over the slower fading 'Flame' dye.

- Developing the daub motif with a single column of light at *five and 10 second* intervals, the ‘Palatinate Purple’ dye had time to fade. This gave the slower fading ‘Flame’ dye the appearance of shifting from behind, to being in front of, the ‘Palatinate Purple’ dye.
- When the daub motif was developed by the whole array and the ‘Palatinate Purple’ dye faded more quickly than the ‘Flame’ dye, a change in the presence of the colours again took place, with the ‘Flame’ dye appearing to dominate the image. As in the previous point, as the **balance of colour changed**, the emphasis within the design also changed.
- When the daub motifs were developed by single columns of light, and observed together as a group, **‘slow’ and ‘fast’ areas of movement** were highlighted. The differences in pace within these areas created a sense of tension and expectation for something else to occur on the screen. Colour mixing by printing may lessen this effect, although it would also add more colours and movement to be incorporated into the design.

Additional effects:

Additional effects, and their shortcomings, that also need to be noted were highlighted:

- When individual colours were developed with a column of light, at the *five second* interval, a fast fading dye had more visual impact, appearing slightly brighter and to take slightly longer to fade than when developed for two seconds.
 - however, this longer time spent developing each column of dye meant more time for the dyes in the previously developed columns to fade. This effect was more marked at the *10 second interval*.
- When the daub motifs were developed with a single column of light at *two second* intervals
 - the effect of the overprinted colours was most clearly seen, as this colour remained on the substrate whilst other parts of the motif were being developed.
 - the lights and the movement of the column did not intrude or interfere visually with the overall effect

At the *five second* intervals

- a lot of colour had faded, but the motif was clearly seen if both dyes were slow fading, however, at the *ten second* intervals the motif was less apparent

as more dye had faded. The lights started to become more noticeable, especially when the difference in the fading times of the dyes was greater, and not much colour remained on the substrate.

As the amount of developed dye colour increased on the substrate the visual presence of the lights decreased.

- When the daub motifs were developed by the whole array at the *five and 10 second* intervals
 - the definition of each motif had more clarity and presence, as colours were of a greater intensity making the overprinted area more noticeable.

Also at the *10 second* intervals

- ‘Oxford Blue’ was clearly visible for several seconds.
- the colour in the peripheral spaces was pale, but of a stronger intensity when developed by the whole array than a passing column.
- the contrast between the colours created as the lights were developing the dyes and the developed dyes was striking. This colour changed the longer the dye was being developed, and subsequently changed the way the motif appeared.

When the LEDs were switched off and the colours of the dyes were able to be seen, the appearance of the motifs changed again as the dyes faded. However, a large block of LEDs developing the dyes meant a large block of brightly shining lights was visible on the substrate. Although it gradually changed colour, it also had a static presence on the substrate.

Filming has been established as a suitable method for recording the dyes and the Flash programme will provide an appropriate design environment to support the next stage of the project.

7.4 Modifications to Large Array and Development of Dyes

The tests in Sections 7.2 and 7.3 have highlighted several ways that the movement and the colours of the dyes could be explored further to determine their ability to create a form of visual narrative. To facilitate this, a larger array directed by software programming that would enable the intensity of current directed to the LEDs, and the amount of time they were switched on and off, so that they could develop the dyes for a defined period of time, to make a prescribed series of patterns that would play in a particular order, as described in Section 6.3, was built. However, before further design

development could commence, a series of exercises was carried out, developing the dyes, to gain familiarity with the array's features. The results of any observations made were noted.

Method used:

Binary code was used to write a series of simple patterns. These were programmed into the array and the way the dyes developed and faded observed. These exercises were filmed and the video files placed in the Flash programme to be reviewed. The software programming for the array was progressively modified in preparation for answering the project aim.

7.4.1 Intensity variation

The ability to vary the strength of the colour of each developing dye would assist with building designs to explore the creation of a changing atmosphere. Therefore, the software programming was modified so that the intensity of the current that lit up the UV LEDs was able to be defined by the user, see Section 6.4.3.1.

Paper, instead of fabric, was initially placed above the lights. Simple designs were programmed into the array to observe how the lights appeared, the sense of movement they created and their intensity. For example, the letters spelling out the word 'BLUE' (design2) showed the LEDs increasing in intensity progressively from 0 to 15, in increments of one, at five second intervals (Fig. 7.22). The alternating letters X and O (design3) showed the progressive increase in current intensity from 3, 5, 8, 10, 12 to 15 (Fig. 7.23). The programming also showed how the lights changed position and how this would translate into the dyes being developed in different places on the substrate at varying intensities.

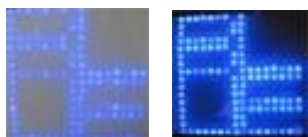


Fig. 7.22 Design2 showing increase in intensity of current to LEDs

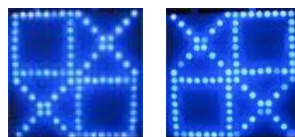


Fig. 7.23 Design3 showing alternating light pattern of X and O

When observing the dyes for colour hue and intensity in Section 5.7.2.2, the cotton drill fabric was consistently placed 3-4mm above the individual LEDs. However, stretching the fabric in the space a few millimetres immediately above the lights of the array created unevenness in its tension, and a subsequent unevenness in its distance from the

LEDs. Therefore, the fabric was placed directly on top of the LEDs. As the current to the lights was not sustained over a prolonged period and the lights remained cool, there was no immediate danger from the combination of heat and fabric. The colour of the printed dyes increased only marginally as a result of this placement.

Developing the dyes:

‘Claret’, ‘Flame’ and ‘Palatinate Purple’ printed dye samples were developed by the array and observed as the intensity of the current was progressively increased and decreased. For example, the pattern sequence used in design3 was altered by increasing the intensity of the LEDs, in increments of one from 0 to 6, to develop the strongly coloured ‘Palatinate Purple’ dye. The time interval was set at three seconds (design4). When this pattern sequence played, the colour of ‘Palatinate Purple’ could be seen to increase in strength, developing finally to dark blue. The dots of dye could be seen to fade when the light pattern changed from X to O, then increase again as they were re-developed at the increased intensity, giving an overview of how the dyes appear when developed in this manner.

Flash programme:

Placing more than one video of the dyes developing on the large array into this programme would increase the size of the canvas upon which a design could be created. When four videos were placed in a square formation their playing speed was unaffected. The shape and size of a canvas may be altered, dependent upon the scale of the dots in relation to it. Cropping the videos enhanced the presentation of the developed designs, giving them a more professional appearance. Using a tripod eliminated the movement to the filming caused by the use of the handheld camera.

Four videos:

Four video clips of design4, developing the fast fading ‘Claret’ dye, were placed in Flash (Fig. 7.24). At the lower current intensities neither the dyes nor the lights had much presence on the substrate. As the intensity of the lights increased they became more dominant, however as they changed position within the pattern, the gradual increase in intensity of the developed dye colour was noticeable drawing attention away from the lights. This occurred for two reasons - the colour of the dye had developed

more strongly on the substrate thereby creating more visual interest and, secondly, there was more colour to watch as it then faded over a longer period of time.

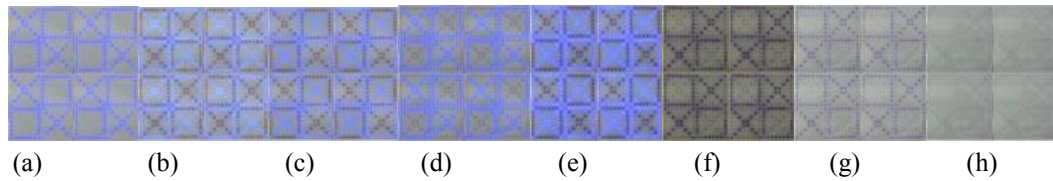


Fig. 7.24 Design4 using 'Claret' dye

The combination of progressive dye development and the repetitive sequencing gave a structured rhythmic format to the pattern. Although at this three second time interval the pattern sequencing appeared calming, it also hinted at how a sense of increasing tension may be built. When used with the appropriate dye, taking its colour and fading speed into consideration, this time interval may be effective for expressing a melancholic and sad mood. When the lights were no longer developing the dyes, the dots appeared like the end of a scene fading away, appropriate for this design aim.

Four videos clips using the same pattern sequence as design4, and developing the 'Claret' dye at one second intervals (design5), were placed on the screen. This time interval caused the pattern to appear very repetitive and static, and may be useful for creating a more urgent sense of momentum, a sense of drama and intensity.

Discussion:

It has been demonstrated that by varying the intensity of current developing the dyes, different effects are able to be created by their interlinked colour and movement. Developing the fast fading 'Claret' dye at the two different time intervals provided an informative contrast, demonstrating the potential to create both a sense of drama and intensity and also a melancholic or sad mood with the same dye. The gradual increase in intensity of the developed dye colour also drew attention away from the lights.

It has also been illustrated that this artificial light source can be used to create a change of pattern with the dyes. The dyes can be developed into one pattern and then re-developed into a different pattern, in the same position, on the substrate.

7.4.2 Repetition control and time delay

The array had initially been set up so that the defined time intervals would be in seconds, however to allow a greater subtlety of change this was refined to milliseconds. The software was also altered so that the number of times a pattern sequence was to be

played could be defined, including the sequence being able to play continuously. This was established by using a negative integer, see Section 6.4.3.2.

Slow fading dye:

A simple sequence that would show a light column moving from left to right, at one second intervals (1000ms), with the light intensity set at five, was programmed into the array. The brightly coloured and slow fading 'Flame' dye was used. The programming used the negative integer and the array was seen to play the pattern continuously.



Fig. 7.25 'Flame' dye developed by single light column

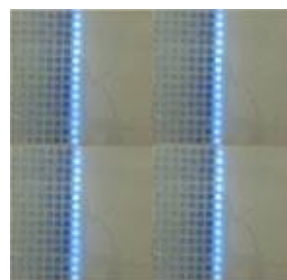


Fig. 7.26 'Palatinate Purple' dye developed by single light column

When the pattern sequence had completed moving across the array, the dye was still visible on all of the substrate, in keeping with its fading speed. The four mounted video clips gave the appearance of one column commencing on the left hand side and another from the middle of the screen, both progressing to the right, as illustrated in Figure 7.25.

Mid-range fading dye:

The 'Palatinate Purple' dye, placed towards the middle of the fading order, was developed by the same sequence, current intensity and time frame. Again, a seamless and progressive fade back of colour was observed (Figure 7.26). The visual effect of the fade back pattern of this faster fading dye gave a more horizontal sense of movement, whereas the 'Flame' dye appeared to move in a more vertical manner (Figure 7.25), like the blocks of colour in Section 7.2.5.

Fast fading dye:

'Plum Red' dye was developed using the same pattern sequence. As its colour strength is not as strong as the 'Palatinate Purple' dye, the current intensity was increased from five to 10. At this higher setting the 'Plum Red' dye still faded more quickly than the 'Palatinate Purple' and the 'Flame' dyes, in keeping with the LED test results of Section 5.7.2.2. There were approximately 2½-3 columns visible to its left as the light source

moved to the right (Fig. 7.27) compared with the 5-6 bars of the 'Palatinate Purple' dye as shown in Figure 7.26.

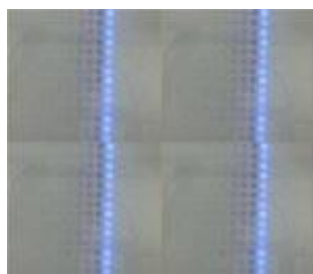


Fig. 7.27 'Plum Red' dye developed by a current intensity of 10

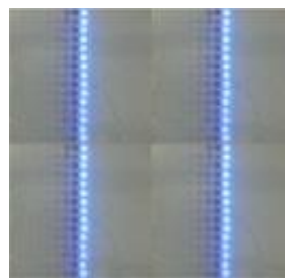


Fig. 7.28 'Plum Red' dye developed by a current intensity of 15

As it appeared very pale, the current intensity was increased from 10 to 15 and the time interval decreased to 500ms, giving a stronger strength of light and a slightly shorter development time. The resulting difference in the colour strength can be seen by comparing Figures 7.27 and 7.28. The enlarged screen size also shows the dye's depth of colour in relation to a larger surface area. Although the current intensity was increased and the development interval was slightly lowered, the fading speed of this dye did not noticeably change. Noting the results of the dyes' measurements in Section 5.7.2.2, this was not surprising. It would be expected, however, that there would be a noticeable difference in the fading speeds of the slower fading dyes and this would be visibly evident on the substrate.

Synchronous sequencing:

In the previous exercise there were four video clips on the screen at the same time, all showing the same pattern at the same time. Although it could be anticipated that a design would vary in different parts of the screen, it could also be expected that at other times the whole of the screen would need to be used for a design. For example, Figure 7.28 shows the columns of lights developing the dyes in a way that was similar to the iris technique, however to do this properly it actually needed to show only the left hand column of lights moving to the centre of the screen and then appearing to continue to the right hand side of the screen.

Initially the clips appeared asynchronously on the screen. After using a trial and error approach, using both printed and unprinted fabric, a way of using the programme so the clips would appear synchronously was accomplished. This meant that the actual actions

of the dyes could be seen and the creation of a larger design, for example, mimicking the iris technique could be more effectively illustrated, as shown in Figure 7.29.



Fig. 7.29 Three photos of the 'Flame' dye mimicking the iris technique.

Discussion:

The larger surface area created by using the Flash programme has been able to effectively illustrate how dyes, from different parts of the colour spectrum with a cross-section of fading speeds, appear when mimicking the iris technique.

It has also been shown that altering the intensity of current to the LEDs enables varying depths of shade of the same dye, and therefore colour, to be used in the same place. This facility will be used to vary the intensity of colour within designs to explore the aim of creating a form of visual narrative by capturing a change of mood with the different colours of the dyes.

7.4.3 Individual matrix intensity control

To assist with creating subtleties of colour within a design, the software was modified so that the intensity of current sent to each of the four matrices could be controlled independently of one another, as explained in Section 6.4.3.3.

Alternating patterns:

To explore the practicality of this alteration, a pattern sequence that showed block areas of colour being developed side by side at different intensities was initially sketched (Fig. 7.30) and then written in code (Fig. 7.31). The binary system proved effective for translating the design patterns into a technical format as the visual appearance of the coding mirrored the way the lights on the array were set out. The figure '1' represents when and where an LED is to be switched on within the sequence. The figure '0' represents when and where an LED is to be switched off within the sequence.

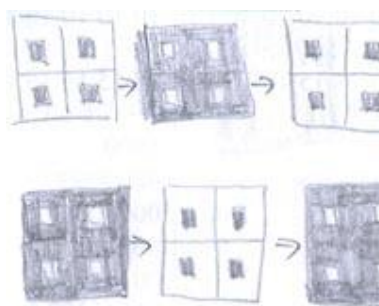


Fig. 7.30 Pencil sketch of design5

00000000	11
00000000	11
00111100	11
00111100	11
00111100	11
00111100	11
00111100	11
00000000	11
00000000	11
00000000	00
	^^

Fig. 7.31 Coding for first and second pattern sequences of each matrix in design5

1
0
-

Fig. 7.32 Intensity settings for design5

The intensity of the lights in each of the matrices differed, with the inner LEDs set at 10, 5, 15 and 1 (Fig. 7.32). The outer LEDs were also set to develop the dyes at these intensities when the pattern changed, see Figure 30. These intensities remained the same throughout the pattern sequence. The timings ranged from 1000-2000ms.

When this sequence developed the fast fading ‘Plum Red’ dye, the colour did not remain on the substrate for long enough to create much visual impact even though block areas of dye were developed. The intensity settings were then slightly modified, followed by an increase in the size of the central area and a change to the timings to improve the presence of this dye. There was little difference in the result, as illustrated in Figures 7.33 and 7.34.

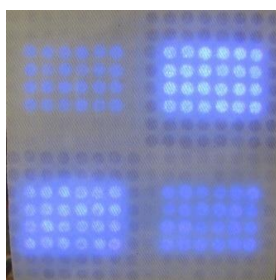


Fig. 7.33 ‘Plum Red’ dye developing first part of design5

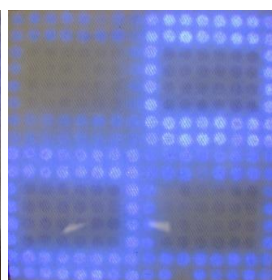


Fig. 7.34 ‘Plum Red’ dye developing second part of design5

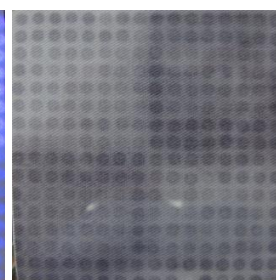


Fig. 7.35 ‘Midnight Grey’ dye immediately the pattern sequence had finished

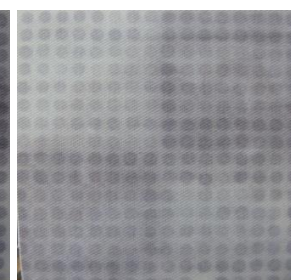


Fig. 7.36 ‘Midnight Grey’ as the pattern sequence faded

The slower fading ‘Midnight Grey’ dye better illustrated the difference in the matrix intensities. Although the lights created a busy scene, once they were switched off, the differences in the depth of shade of the dye developed by each of the matrices was able to be clearly seen (Figs. 7.35-7.36).

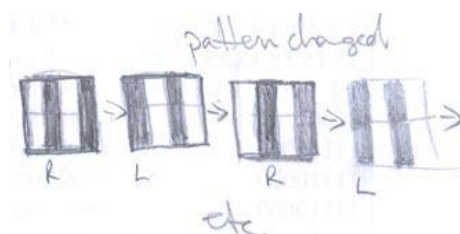


Fig. 7.37 Pencil sketch of design7

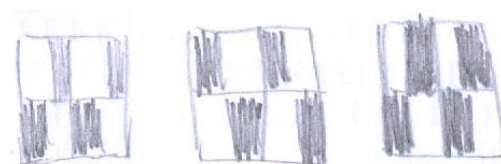


Fig. 7.38 Pencil sketch of design8

A step back to a less complex design was then made by alternating the development of the dyes from the right to the left hand sides of each array, see design7 in Figure 7.37. Design8 then enlarged on this design (Fig. 7.38). Although no further insight was gained for design development, both sequences coordinated the programming of the four arrays and illustrated the differences in the intensity of current used.

Colours of the dyes and lights:

In Section 7.3.2 it was noted that the combination of the colours of the dyes whilst they were being developed by the light source differed from dye to dye and depended upon the strength of current used.

Dye	Current Intensity 2	Current Intensity 6	Current Intensity 10	Current Intensity 15
'Oxford Blue'	white	white	white	white
'Aqua Green'	white	white	white	white
'Sea Green'	white to light blue	white	white	white
'Palatinate Purple'	white to light blue	white to light blue	white to light blue	white to light blue
'Cardinal'	white	white	white	white to light mauve
'Plum Red'	white to light blue	white to light mauve	white to light mauve	white to light mauve
'Claret'	white to light blue	white to mauve	white to mauve	white to mauve
'Corn Yellow'	pale pink to pink	pale pink to pink	pale pink to pink	pale pink to pink
'Volcanic Grey'	white to pale pink	white to pale pink	white to pale pink	white to pink
'Flame'	white to pale pink	pink/orange	white to orange/pink	white to orange/pink
'Midnight Grey'	light bright blue to bright blue	light purple to fluorescent blue/mauve to bright fluorescent blue/mauve	light purple to mauve to bright mauve	bright blue/mauve to fluorescent mauve to fluorescent mauve/blue

Table 7.6 Combined colour of the light source and the dye

Therefore, the dyes and lights were observed and a guide to these different colour combinations was compiled (Table 7.6). It can be seen that the combinations of light and dyes range from white, light blue, bright blue, pale pink, pink, mauve to orange pink. Although designs will be based on the colours and the fading speeds of the dyes, knowledge of the colours that these combinations create may be useful as design work develops further.

Discussion:

The different strengths of colour that will be able to be used within each matrix, combined with the amount of time that the dyes will be developed, increase the scope and complexity of pattern development.

7.4.4 Individual column intensity control

Controlling the intensity of the electrical current to individual columns of LEDs would enable pattern and colour development to be further refined. Pattern sequences were written showing the columns of lights changing in intensity and subsequently developing the dyes. A flickering effect was created by the columns of light as the intensity changed from one column to another.

Discussion:

The amount this effect will be used will be determined by the designs made. Certainly a further sense of movement is given to the dyes however the presence of the lights within a larger design will need to be considered.

7.4.5 Summary

The exercises on the larger array were mainly to gain familiarity with its features so that the findings in Sections 7.2 and 7.3 will be able to be explored further. Its programming has given improved fluidity to the development of the lights and this translates into a more fluid development of the dyes.

The screen size of the four arrays, made by using the Flash Programme, provided a platform on which to show the dyes developing and fading on a larger scale.

Using different time intervals to develop the dyes, the rhythm of momentum and tension created by the developing colours is able to be varied. Additionally, the ability to alter the different strengths of colour within each matrix enables the same dye to be developed into different shades in the same place on the substrate. It has also been illustrated that this artificial light source can be used to re-develop the dyes into a different pattern, in the same position, on the substrate.

7.5 Summary

This chapter has looked at the development of the dyes by both a small manually controlled array and a larger software programmable array.

Simple tests were carried out on the small array, initially keeping to a minimum the number of factors involved. Guided by each of the results, and an understanding of how the functions of the array directed the dyes, the complexity of the tests was progressively increased. The results continually emphasised that when using these dyes they will always be fading and it is a continual action. Once they have been developed by the LEDs and their fading begins, this movement is not able to be halted, although the dyes may be re-developed at any stage during the fading process.

The potential of the dyes to create a form of changing imagery have been illustrated in the following ways:

- The LED array can be used to create one pattern with the dyes and this can be changed to re-develop into another pattern, in the same position on the substrate, using the same colour of dye.
- The resulting visual effect and the fading sequence created when the light pattern used to develop the dyes does not directly correspond with the printed design may enable two very different images to be created.
- An alteration in the perception of depth within a design can occur, depending upon the hue, intensity, fading speed and placement of the dyes and the way in which these elements are used together.
- The dyes have been shown to display a sense of forward (sideways) movement, with varying degrees of momentum and tension created by the time intervals used for their development and their subsequent fading speeds.

The exercises on the larger array were mainly to gain familiarity with its features so that the findings in Sections 7.2 and 7.3 could be further explored. It provided a larger platform for the dyes' development and this was further increased when four arrays were placed together making a larger screen.

Binary code defines the current sent to the LEDs that then develop the dyes. Altering the strengths of current within each matrix enables different shades of the colour of each dye to be developed. The time interval for the dyes' development is also able to be

defined and, as has been illustrated by the 'Claret' dye, differences in momentum and tension are able to be created.

These results show that there are several ways to potentially create a sense of narrative and changing atmosphere within a design and they will be explored with that aim by employing the different colours and fading speeds of the dyes.

7.6 References

[7.1] Belien & Bongers [WWW] <http://www.youtube.com/watch?v=9DJr8QwgLEA>
Accessed 18/12/11 (2010)

Chapter 8

Design Development

A spiritual teacher from India once pointed out that there is no such thing as a grey sky. The sky is always blue. Sometimes, however, grey clouds come and cover the blue sky. We then think the sky is grey [8.1].

Design Development

8.1 Introduction

During the early stages of this project, techniques and methods typically used within the design process, such as collecting imagery and mark making, were explored to gain inspiration for ways of using the dyes to show a change from one colour and/or design to another, with the aim of creating a narrative effect. Additionally, information on French Impressionist films and colour was collated and then narrowed down to those aspects considered most relevant to the project aim. The experimental testing in Chapter 5, based on traditional design methodology, led to a working knowledge of the dyes. This was followed by tests on the small and large UV arrays that were based on design questions considered necessary to understand the dyes' development by these devices, with the results making it clear that a new methodology was needed to create printed designs that can move. The knowledge accumulated from all of this work informed the subsequent design development that ultimately led to the creation of a series of sequences that illustrated the way that a visual narrative can be created using the colour and the movement of the dyes.

8.1.1 Imagery and mark making

Initially imagery of natural phenomena such as drought, bush fires, floods and plant life were considered because they illustrate change. These ideas were storyboarded in pencil and also illustrated in Photoshop. Scenes from the environment that presented as suitable for mimicking, and reminiscent of, the stylistic film techniques, were photographed and/or filmed, for example, tree canopies, rippling pond water and clouds.

Mark making exercises were carried out, in a range of densities, using both pencil and Photoshop. Scale and shading were explored in both A4 and A3 formats, with small and large-sized daub marks. Using Photoshop, filters were applied to some of the marks to re-create the stylistic techniques in 2D form.

Although it was constructive to explore these aspects of design, it was decided that any further progression of this work, at this stage, would have been premature as the light source that would be developing the dyes had not yet been identified. These exercises, however, encouraged thought about how to proceed particularly with regard to the practicalities of developing the dyes and the equipment that would be needed. Figure 8.1 shows examples of this work.



Fig. 8.1 Examples of initial imagery, storyboarding and mark making

8.1.2 Colour and mark making

It was noted in the Literature Review that words associated with reds, oranges and yellows often imply optimism and warmth and a positive sense of energy, whereas words associated with blues, purples and greys are often related to depression and dullness conveying a sense of slowness and lethargy. However, the colour research collated in Chapter 4 was invaluable, showing that colour can be used in diverse ways, either singly or in combination, to convey moods from opposite ends of the emotional spectrum. It also showed that colour choice is very personal to the user and artists and designers are able, via colour, to bring out certain emotions in the viewer or to transport them emotionally from one place to another.

The application of paints and dyes by selected artists and textile designers informed my thinking about the way effects are created with familiar static dyes and how this may be translated to the movable photochromic dyes. The effect their work created, that is, the emotions that were able to be evoked and how this was achieved by imagery and layering and floating effects, among others, were also noted. The initial intention was to adopt selected mark making techniques and use them to apply the dyes to the substrate, noting their effectiveness when used with a medium that is transient. Although it is common practice to experiment with techniques used by others, the research highlighted the direct relationship between the marks made by the artists and designers and their chosen medium.

The method of ‘applying’ the photochromic dyes to the substrate would be via LEDs, the structure of which causes the colours of the dyes to emerge from the fabric substrate

in the shape of dots. After considering the results of the tests in Chapter 7, it was decided to use only these marks as the means for building designs, enabling attention to be focussed on the dyes' movements and their linked colours, so that these aspects, that give the dyes their uniqueness, could be properly explored. Transposing different mark making techniques could be carried out in future work.

8.1.2.1 *Dot mark*

The use of small marks or dots, whether circular, square or daub-like, was a repetitive theme within designs and products when collecting imagery during the research. In the nineteenth century, the pointillist technique used dots as a way of applying colour with the paint brush to build an image. Contemporary artist Guyton/Walker's screen printed designs are made up of dots (Fig. 8.2) and contemporary lighting installations use circular or square shapes to combine colour and light (Fig. 1.16, p.14). This motif is also used as decoration, for example, Sandi Kiehlmann's copper light installation (Fig. 8.3), or as part of the construction of a product, for example, wall tiles.

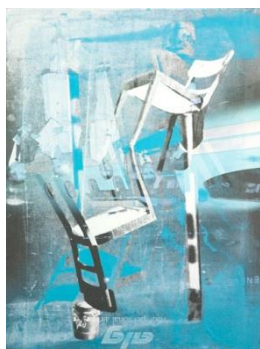


Fig. 8.2 *Untitled (Light Blue Chair)*, 2005



Fig. 8.3 Copper light installation, 2000

Within the field of textiles, Inge Heuber uses fabric squares to make quilts (Fig. 4.49, p.68) and Raymond Honeyman paints dots of colour to map out his tapestry designs, creating depth and shadow by altering the strength of a colour (Figs. 4.56-4.57, p.71). Additionally, the configuration of the material created by woven threads and the stitch mark made when sewing a design are both reminiscent of the pixels that build up images in Photoshop and electronic displays. The coloured dot, that is made as photochromic dye is developed by LEDs, is therefore a fitting mark for building imagery on a fabric substrate. It also literally links the two fields of technology and textile design.

8.1.3 New methodology

The experimental testing in Chapters 5 and 7 was based on traditional textile design methodology that provided a solid baseline of tacit knowledge against which the testing of the photochromic dyes could be carried out. It also enabled the differences in their behaviour and that of traditional dyes to be progressively highlighted. It increasingly became apparent that the unique aspect of movement that the colours of the dyes possess influences the way they can be used, as the following examples demonstrate.

Although aware that the 'Aqua Green' dye was faster fading than the 'Cardinal' dye, a simple print of a traditional image consisting of 'apples' on a tree was made to observe the effect that the dyes' movement had within a simple design (Section 5.3.5). Although the action of a print fading from a textile substrate is not usual, it could have been expected that in this simple design the apples disappeared from the tree whilst the outline of the tree remained (based on our understanding of nature and how it is constantly replicated by us). However, the fading speed attached to the colours meant the tree faded leaving the red dots or 'apples' visible on the substrate. This lack of a conventional, or assumed, outcome opens the possibility for something other than what would be expected with a change of imagery to occur. For example, if combined with additional colours developing and fading, the red dots left on the substrate could become part of another different and morphing design.

The dyes were developed in a controlled manner by the small array, as discussed in Section 7.2.14. The purpose of the testing on this device was to understand the coordination of their development and the effect this had on their appearance as they faded. Although their fading speeds were known, their presence and how they appeared as they interacted together needed to be understood. These tests subsequently highlighted that a different approach to designing, when developing the dyes in this way, was required.

The elements of colour, proportion and placement that are related to traditional design practice are used instinctively by a designer. However, when using photochromic dyes the introduction of movement altered the way these three elements are perceived and therefore able to be used within two dimensional design. The tests illustrated that:

- the colour of the dye is either visible, slowly disappearing or invisible depending upon whether it is fully developed, partially faded or fully faded

and this affects its presence on the substrate. Its colour determines what hue we see - for example, whether it is blue or orange - and the effect that colour has within the moving design and on us as the viewer. Its fading speed determines how long that colour will be visible and its depth of shade at different times.

- the placement in which the colour is used determines where on the substrate there will be, at particular times, a particular colour that has a certain hue and an attached fading speed. Where the colour is placed and how it fades will also affect the design by its impact, at different times, upon other printed colours and shapes that are also at different stages of development or fading.
- the proportion in which colour is used directly defines the amount of substrate that will be, at any time, either coloured, lightly coloured or uncoloured and the effect this will have on the overall design.

These factors indicate that the emphasis when using these dyes is on how the colours are linked with one another, that is, their placement and sequencing, thus bringing together their performance parameters which are not as dependent on, or as linked to, the traditional design process. Therefore, the test results will be carried forward and a more calculated approach, based on linking the movement and the colour that is attached to it, will be used. This method will therefore lean the design process more towards the technological approach, as it has become less tacit and less intuitive. However, the intuitive aspects of design still have their place. The choice of colour, proportion and placement, and the added dimension of movement will still be made by the designer although within the boundaries of the technology. This way of working will also enable the effect created, when developing the dyes by artificial UV light, to be managed much more than when relying on the development of the dyes by the sun.

8.2 Combining Colour and Movement

Methods have been identified that show how photochromic dyes can be used to create a change of image, how colours can change from one to another and techniques, incorporating the dyes' fading speeds and varying their development intervals, can be used to create a greater or lesser sense of tension. Based on this information, a range of design ideas were sketched. Concurrently, the changing colours and shapes of clouds and those of the man-made kaleidoscope were observed, for the purpose of noting how their moving colours create the effects that are capable of evoking a range of feelings in us as we view them.

When the practical work began, the results of one design test started informing the development of the other designs, causing the process of exploring each of the design sequences concurrently to begin. It was soon decided, however, to return the research focus back to where it appeared to most directly answer the project aim and this was done by exploring the movement and colours of the dyes using the cloud formations as inspiration. However, as stated in Section 8.1.4, the emphasis when using these dyes is on how the colours are linked with one another, that is, their placement and sequencing, and it became apparent that, although there were strong parallels between the clouds' movements and colours and those of the dyes, the way these two elements could be used together was not as effective as it initially seemed. In practice, the images did not appear to provide what was needed to explore another aspect of the dyes' movement - tension, without it seeming that they were just shapes of colour appearing and disappearing. The decision was therefore made to bring together the information that had so far been highlighted and apply it in another way, using the sea and sand for inspiration.

Method for printing:

As in all previous sections, the print pastes for the selected dyes were made using the relevant method as described in Section 5.2.1 or Section 5.2.2. Due to the difficulty of lining up the prints, as discussed in Section 5.3.2, and their size, it was decided to use paper stencils. This proved to be a simple and very efficient way of aligning the dyes. The printing equipment as described in Section 5.2.4 was still used in the same way and the prints were finished following the method as described in Section 5.2.5.

Method for development of dyes by array:

A template of the array was drawn on which to map out the sequences in which the lights would develop the dyes. Each change of lights was filled in on a separate template and the relevant binary code could then be written based on these patterns. A sheet of paper was placed over the lights to check the development of each sequence before it was used to develop the selected dyes. For practical reasons this work using the array was carried out at my work space where the temperature of the air conditioned room was set at a consistent $21\pm1^{\circ}\text{C}$. The effect this had on the colours and fading speed of the dyes appears to have been visually negligible. The dyes used are illustrated at the beginning of each written section.

As the dyes were developed they were photographed and/or filmed. Although filming was important for repeatedly observing the movement of the dyes, storyboarding photographs remained, for the visually thinking designer, the most useful technique for planning and reflection. Selected photographs illustrate the relevant points from tests, with the remainder set out in sketch books.

8.2.1 Narrative effects

As the narrative effects noted in Section 7.2 and 7.3 were very subtle, the aim was to apply them within a design to see if they could be more clearly and strongly demonstrated. The effects that showed the potential for creating visual narrative, by developing the dyes with a single light column moving from left to right, were:

- a sense of forward momentum
- the development of a fleeting image
- the creation of variations in tension
- the illusion of depth

This information was visually collated by sketching (Fig. 8.4) and highlighted that these effects are interlinked with one another. For example, the development of a fleeting image is created by the dyes being developed by a column of light moving from left to right and this also creates a subtle sense of the image moving forwards (carried by the momentum of the dyes being progressively developed). The illusion of depth created is affected by that column's speed of progression whilst the sense of tension created by the column, as it develops the dyes from left to right, is interrupted by the different fading speeds of the dyes when more than one colour is developed.

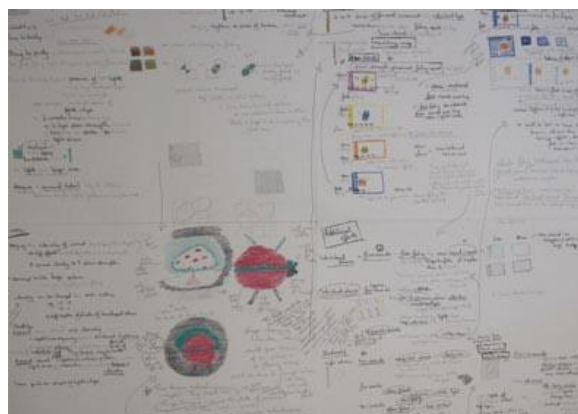


Fig. 8.4 *Design Planning 1*

Some of these effects showed similarities to certain stylistic techniques. For example, variations in the intervals used to develop the dyes when creating a sense of forward momentum and when creating a sense of tension correspond with rhythmic editing. The illusion of depth corresponded with the technique of superimposition.

8.2.2 *Stylistic techniques*

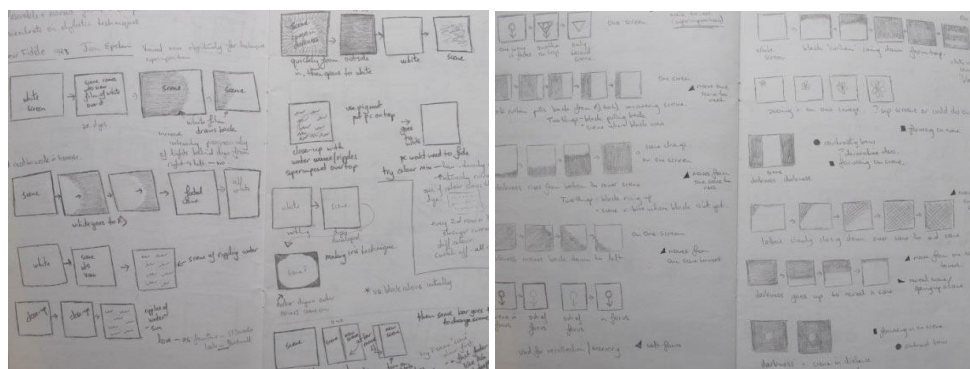
As French Impressionist films are a moving medium, their stylistic techniques gave concrete methods that could be applied to these ephemeral dyes and against which their capacity to move could be observed. Therefore, the techniques were sketched and re-sketched in story board form. The main techniques used were then further analysed by going backwards and forwards between the films and my sketched observations, to define the actual movements and give clarity to ideas about re-creating them with the dyes.

The techniques were then narrowed down, by sketching, to those where the movement of the dyes could be explored within the movement of the technique, with the aim of showing a change in colour or a change in the sense of atmosphere created. The selected techniques were:

- end of film (split screen effect, close-up and fade out)
- wipes, fade outs/fade ins
- iris technique
- slow motion/fast motion

Techniques that were used to create specific effects could be explored in future work.

The selected techniques were then sketched out in groups according to the action that they performed within the film, for example, moving from one scene to the next or superimposition. This process highlighted that many of the techniques were variations on a set of basic movements and these were then grouped together.



The experimental testing that was concurrently carried out in Chapters 5 and 7 brought new knowledge and understanding about the way the dyes appear as they develop and fade, and allowed the techniques that were being explored to be narrowed down further to isolate those considered most relevant to the project. This work is contained in sketchbooks (Fig. 8.5)



Fig. 8.6 *Design Planning 2*



Fig. 8.7 Part of *Design Planning 2a* sheet

The isolated film techniques were sketched (Fig. 8.6) and knowledge gained from the tests in Chapter 7 was used to consider how to re-create these with individual or mixed dyes. They were identified as being either useful for illustrating the movement of the colours or for creating a definite change of image. Some techniques were considered impractical as their replication would require the lights to re-develop the dyes as they were still fading, unnecessarily increasing their presence without enhancing the sequence, or they were not directly related to answering the project aim.

8.2.3 Ideas and inspiration

The remaining stylistic techniques were mapped out on design sheets (Fig 8.7) beside the narrative effects that had previously been identified and sequences for developing the dyes, sometimes combining both means, were then considered, with alterations made according to the dyes' known capabilities. Ideas began to emerge and design sequences were sketched. Research into the colour changing of clouds and the kaleidoscope was also carried out.

8.2.3.1 Tree, bug and planet

The figurative sequence of the *Tree, bug and planet* showed one image changing to another. Two simple images were drawn to illustrate how developing dyes, in the same position on the substrate, with two different light sequences, could be used to create two different designs (Fig. 8.8). This idea was developed further to illustrate three or four different, albeit simple, designs (Fig. 8.9). The intention was to develop each by selected lights in a single column, as it moved progressively from left to right, only developing the specific dyes of that particular image. This would then be repeated with a different light pattern, developing the same dyes, in a different formation. It would also be creating a method similar to that of the film technique of superimposition.

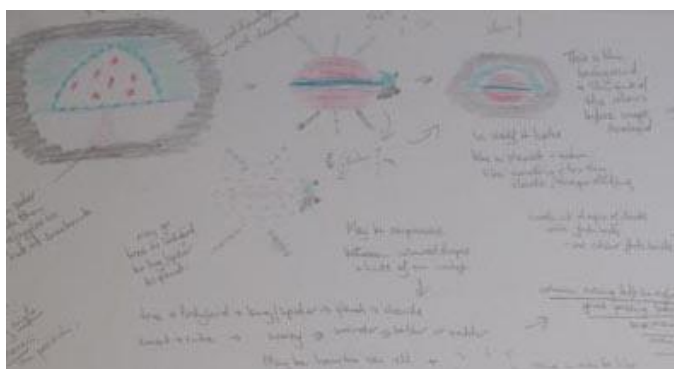
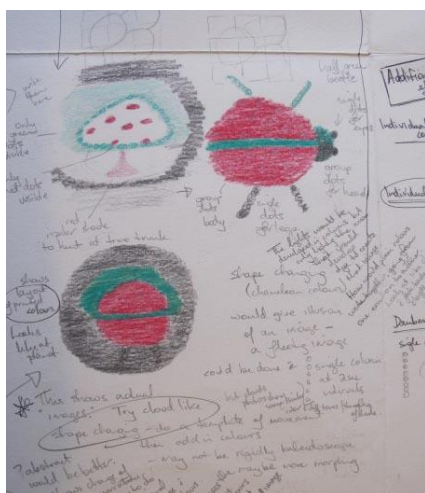


Fig. 8.8 Close-up from *Design Planning 1* Fig. 8.9 *Design Planning 1a*

8.2.3.2 Clouds

Influenced by Turner, the sky provided a canvas for observing changing colours and shapes in the form of clouds. Their movement appeared overall to be horizontal, although on less windy days their shapes changed whilst they appeared to remain in the same position. Photographs of their varied colours, shapes and movements were taken and set out (Fig. 8.10). Often taken in series, these showed the progressive changes in

the clouds' shapes and the accompanying shift in the placement and tone of their colours. The effects varied from two or three easily defined colours in very simple and calm arrangements to more turbulent and stormy scenes. For example, one series shows a change from a fierce and vibrant orange, yellow and dark grey group of clouds to a softer and calmer pale pink, light grey and white group. Although the textural appearance of the clouds contributed to their increased sense of movement, the photos clearly showed that a change in the combinations of colour and the depth of their shade created a change in the atmosphere of the sky. The more texture in an image and the stronger the intensity of colour (regardless of its hue), the more emotive it appeared, whilst less texture and a lighter colour created a calmer, more serene scene. These effects were noted. Ways of re-creating these effects, using the intensity of the dyes' colours, and the placement and the fading of mixed dyes, were considered.



Fig. 8.10 *Photos of clouds for colours 1 and 2*

A stylised image of a pink, yellow and white flower blooming and changing into a blue sky with white and grey clouds was shown in a video [8.2]. This changing image was observed every second over a one minute period enabling the placement of the colours, as they changed step by step, to be seen. The colours of the flower were shown fading as the new image of the sky and clouds gradually appeared. This exercise assisted with working out how the colours of the dyes may be placed and how they would need to be developed to create a similar change in colour. To progressively introduce a new image would require the repetitive development of the dye by the LEDs, and therefore, also,

the creation of repetitively visible circles of light, as noted in Section 7.4.1. It also highlighted the effect that the different fading speeds of the dyes, related to the colours, may have within a design and how this will need to be considered.

8.2.3.3 *The kaleidoscope*

The word kaleidoscope has been defined variously as ‘a continually changing pattern of shapes and colours, continually changing symmetrical forms, a continually shifting pattern, scene, or the like’ [8.3]. By observing their colourful shapes and patterns, as they slowly change, the effects created by the different combinations could be seen [8.4] and how these affect the viewer could be felt.

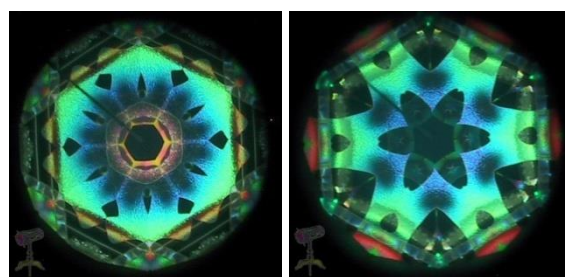
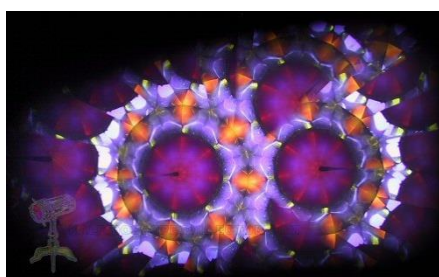


Fig. 8.11 Images created by a kaleidoscope [8.5] Fig. 8.12 Images created by a kaleidoscope [8.6]

The patterns created in the kaleidoscope are intricate (Figs. 8.11-8.12), made up of multiple colours that appear to change within the same position and in sideways movements, and they vary in complexity [8.7] [8.8]. Placing different coloured dyes in similar arrangements would interrupt any smooth sequential colour development and this would equally apply if the dyes were developed in varying directions on the substrate. The different fading speeds of the dyes would define areas of ‘fast’ and ‘slow’ colour on the substrate and these would not alter.

Although the patterns of the kaleidoscope appear more complex than the movement of photochromic dyes would be capable of achieving, using different wavelengths of UV light to develop both individual and mixed dyes may increase the variety of colours that are able to be developed. Exploring their colours when they are developed in this way, coupled with selective placement may enable a similar effect to the kaleidoscope to be created. This would require a more complex light source to be built. It would be an interesting area to explore in future work.

As the movement of clouds is less complex than that of the kaleidoscope, giving a simpler baseline against which to inform the placement of the dyes, it was decided to use this imagery as a reference against which to initially create pattern development.

8.2.4 Design development

8.2.4.1 Fading stripes

The Reversacol dyes used for testing were:



After considering the placement of the colours within the sketched design sequences, it was decided to firstly develop a series of stripes, each the width of three columns of LEDs, using selected dye pairings. Observing the changes in the balance of colour and the movement of the dyes when developed by the larger-sized array would inform the placement of colour when planning the cloud-like shapes.

'Flame' and 'Palatinate Purple', 'Claret' and 'Corn Yellow', 'Sea Green' and 'Cardinal', and 'Volcanic Grey' and 'Sea Green' combinations were chosen based on the dyes' fading speeds and their placement on the colour wheel. An additional print using the mixed colours of 'Volcanic Grey' and 'Sea Green' placed between individual 'Volcanic Grey' and 'Sea Green' stripes was also made, to observe the variations in the shades and fading of these colours when placed together. The intensity was set at 15 and the time interval at 1000ms.

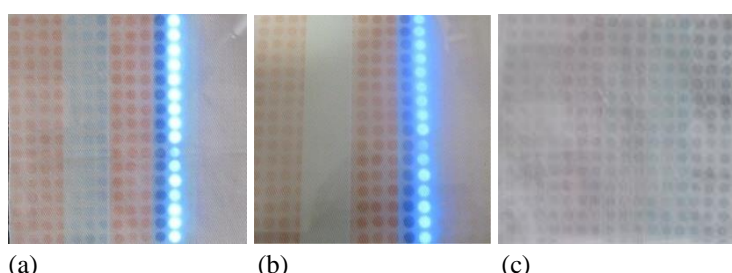
Each pairing was developed by a single light column moving from left to right, to note if there was any sense of forward movement of the colour combinations. They were then developed, in the same way, by a double light column. The stripes were also developed alternately to observe how the colours appear as they fade and develop beside one another. Any sense of rhythm to their movement would be noted.

Results and Discussion:

When each pair of dyes was developed by the single light column, the 'Flame' and 'Palatinate Purple' and 'Claret' and 'Corn Yellow' pairs, that have the greatest contrast in fading speeds, showed the greatest contrast in movement between each of the colours, however the slower fading dyes in each pair appeared to periodically interrupt any sense of forward movement (Fig. 8.13.a).

Based on these results, the 'Flame' and 'Palatinate Purple' stripe was developed by the single light column at two second intervals to compare the difference between the two time frames and note the effect this had on the change of colour balance. As the 'Palatinate Purple' dye had an extra second to fade each time another column was being developed, the 'Flame' dye was more dominant on the substrate than when one second intervals were used and the 'Palatinate Purple' dye remained visible for slightly less time, as can be seen when comparing Figures 8.13.a and Figure 8.13.b.

When developed by two columns of LEDs the colours of the dyes appeared a stronger intensity than when developed by a single column because the two light columns reached the end of the array more quickly than the individual ones, giving less time for the dyes to fade. This reinforced that a balance needs to be found between the amount of time the dyes are developed and the amount of time they take to fade. Being developed by two columns also caused the dyes to appear to fade as blocks of colour into the substrate, even if they had contrasting fading speeds.



(a) 'Flame' and 'Palatinate Purple' dyes developed with single light column at 1 second intervals
 (b) 'Flame' and 'Palatinate Purple' dyes developed with single light column at 2 second intervals
 (c) Stripes of 'Volcanic Grey', 'Sea Green' and 'Volcanic Grey' and 'Sea Green' mixed dyes

When developed alternately, the 'Flame' dye faded very slowly beside the 'Palatinate Purple' as did the 'Corn Yellow' beside the 'Claret', whilst the 'Sea Green' and 'Cardinal' dyes remained on the substrate for a similar amount of time. The 'Flame' and 'Corn Yellow' dyes each then dominated their respective stripes as the 'Palatinate Purple' and 'Claret' dyes faded. When the same sequence developed the dyes twice in succession, the slower fading dyes were being re-developed before they had faded.

Based on these observations, using two fast fading dyes may create a faster sense of rhythmical movement. Developing both slower fading dyes alternately and combined slower and faster fading dyes alternately over a longer period of time may demonstrate the potential rhythm that both the faster and the slower fading speeds of the dyes could create in varying combinations. However, it was decided these effects could be

explored further in future work, as the dyes were not going to be used in this specific proportion and placement.

When developed by the single column and alternately, the difference between the developed colours of ‘Volcanic Grey’ and ‘Sea Green’ and the ‘Volcanic Grey’ and ‘Sea Green’ mix was both clear and subtle (Fig. 8.13.c), illustrating that if used in the appropriate placement and proportions variations of shade created by the mixed dyes could also be used.

When the lights were developing the dyes at one second intervals their initial brightness receded as they were replaced by the combined colour of the lights and the dyes.

Based on the results of these observations, and that continued development of the dyes in these placements, although interesting, would move the project away from the design aim, it was decided to observe a few dyes being developed in a more complex arrangement to gain a further understanding of how they interact and appear on the substrate, with the intention of using this information when making cloud-like designs.

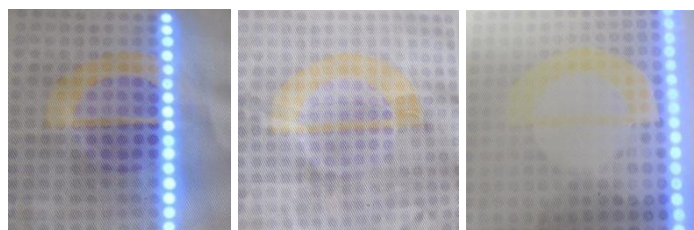
8.2.4.2 *Tree, bug and planet*

‘Claret’ : ‘Corn Yellow’ : ‘Volcanic Grey’



Based on the results of Section 8.2.4.1, the *Tree, bug and planet* design was printed using ‘Claret’, ‘Corn Yellow’ and ‘Volcanic Grey’ dyes. A single column of light initially developed the whole image to observe the colours in their placement and their fading speeds against one another (Fig. 8.14.a). The intensity was set at 15 and the time interval at 1000ms.

Results and Discussion:



(a) (b) (c)
Fig. 8.14 a. *Tree, bug and planet* being developed at one second intervals
b. *Tree, bug and planet* developed at one second intervals fading
c. *Tree, bug and planet* being developed at two second intervals

Due to the slow fading speed of the ‘Volcanic Grey’ and ‘Corn Yellow’ dyes there was no sense of a fleeting image and the colours appeared quite flat (Figs. 8.14.a-8.14.b). Based on the results of Section 7.3.1.2 the time interval was increased to two seconds to give the dyes longer to fade. Overall this gave the image stronger definition, as the dyes were developed to a stronger intensity and the fading of the ‘Claret’ dye was more noticeable (Fig. 8.14.c). It also gave the image a more fleeting appearance as can be seen by comparing Figure 8.14.b with Figure 8.14.c. It also highlighted that balancing the different colours and their individual fading speeds against one another, to create imagery that, although abstract, potentially had some semblance of recognisability, would be more complicated in practice than it initially appeared.

The intention was to next use a light pattern to develop parts of the dyes so that each different image would be developed individually. Once their development was seen, any alterations could be made so the design could then be re-printed and re-developed using the faster fading dyes of ‘Palatinate Purple’, ‘Sea Green’ and ‘Plum Red’. However, even though testing on this design sequence had begun and a change from one image to another in a series may be able to be achieved, it was felt that this work was moving the research away from the main aim of the project. It was therefore decided to move directly to concentrating on exploring the changing colours and movements of cloud-like shapes.

Firstly, though, based on the results of Section 8.2.4.1 and Section 8.2.4.2, it was decided to take a step back and begin by developing the simple formation of the circular iris technique. As stated in Section 8.2.2, some of the stylistic techniques were used in films to move from one scene to the next and that is how they will initially be explored when developing the dyes.

8.2.4.3 Circular and square iris techniques

The Reversacol dyes used for testing were:



Based on development sketches of the stylistic techniques (Fig. 8.5), a light pattern mimicking the circular iris technique was programmed into the array, to develop the

dyes in both an inwards and an outwards direction, with the intention of determining whether it could be used, wholly or partially, to indicate that a change in any pattern was to occur.

The initial results of the *Tree, bug and planet* print informed the choice of dyes. ‘Sea Green’ was chosen as it sat midway on the fading spectrum, ‘Palatinate Purple’ fades more quickly than the ‘Sea Green’ whilst ‘Plum Red’ is bright and one of the fastest fading dyes. The dyes for the combined colours were chosen by referring to the photographs of the clouds and then looking at the colour mixes carried out in Section 5.4.4. Based on the intensity of colour when the dyes are developed together, the combinations of ‘Flame’ and ‘Midnight Grey’, ‘Palatinate Purple’ and ‘Claret’, and ‘Cardinal’ and ‘Palatinate Purple’ were chosen. Although it was anticipated that the faster fading pairs would give faster movement and faster fading patterns, it was decided to develop these combinations to observe how the slower fading dyes appeared in this formation at this larger scale. The intensity was set at 15 and the intervals of development decreased to 700ms.

Results

The effects of the three individual dyes were compared against one another. The ‘Sea Green’ gave a sense of completion as its colour remained covering the whole substrate when the pattern development had ended in both directions (Fig. 8.15).

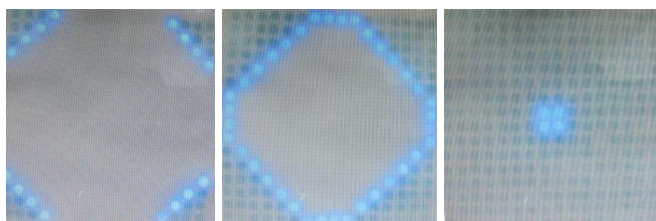


Fig. 8.15 ‘Sea Green’ dye developing inwards in the iris formation

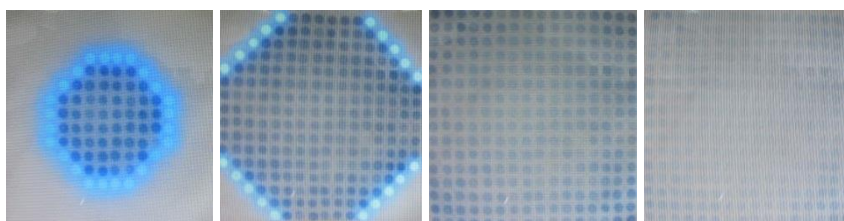


Fig. 8.16 ‘Palatinate Purple’ dye developing outwards in the iris formation

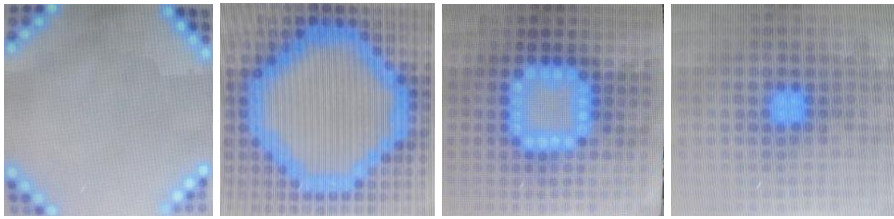


Fig. 8.17 'Plum Red' dye developing inwards in the iris formation

The 'Palatinate Purple' dye could be seen to be fading softly as it was developed and may be effective in showing that it was opening up to the development of another image (Fig. 8.16). The 'Plum Red' dye gave the most definite illustration of change as it could be seen to begin fading progressively (Fig. 8.17) as soon as each circuit of dye was developed. The lower time interval gave a subtly faster rate of development than the one second intervals in the previous designs and gave a slightly more flowing feel to the effects that were seen.

The combined slow fading 'Flame' and 'Midnight Grey' dyes created an orange-brown colour that covered the whole substrate until it began to noticeably fade. The subtle addition of 'Claret' to the 'Palatinate Purple' dye could be seen in that pair's colour mix though the 'Claret' faded quickly. When the combination of the 'Cardinal' and 'Palatinate Purple' dyes was developed in an outward formation, a subtle hint of light 'Cardinal' pink was visible on the substrate as the lights moved out to the edges of the array. This was probably because the placement of the dye on the substrate in this formation.

These results reinforce that the speed of development of the dyes affects the sense of tension that is created. 'Plum Red' would be the initial choice of dye if a more immediate indication that a change of sequence or atmosphere was about to occur was wanted. Its intervals of development could also be decreased to increase the sense of tension if that was desired. The slower fading dyes could be used if a calmer feel was required. The combined dyes may also be able to be used within this technique, with the colour combinations to be used based on the desired colours and speeds of fading. If the whole design was made on a larger scale the dyes would have more time to fade so the effects that are being created may be more clearly seen and better defined.

The development of the dyes in the shape of this stylistic technique also provided another way for observing their appearance as they faded, with regard to the proportion of dye colour that remains visible on the substrate.

The above results are based on the whole of the iris sequence being developed. If this effect was to be used in conjunction with a design consisting of more than one dye, the fading speeds of the dyes used within the body of the design would alter the rhythm of the iris sequence so perhaps only the outer parts of this effect could be used. Therefore, its use will be considered in combination with the designs created, once they have been developed.

Square iris technique

Developing the dyes in a square iris technique may create the sense of a more rigid transition, and if so, could be used to indicate that a change to a more tense atmosphere was to follow in the next sequence. ‘Palatinate Purple’ and ‘Plum Red’, as the faster fading dyes, were used to create this formation.

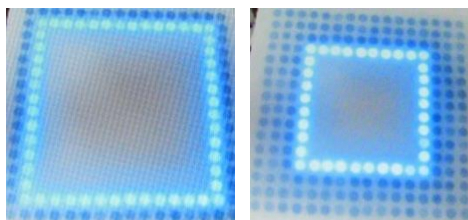


Fig. 8.18 ‘Palatinate Purple’ dye developing square iris technique inwards

As the square shape developed (Fig. 8.18) it appeared more angular than the circular one, however it would need to be placed within a sequence to determine its effectiveness as an alternative transitional technique.

8.2.4.4 Clouds

The Reversacol dyes used for testing were:



Observing clouds revealed that they change shape as they move horizontally and within the same space, whilst the findings of the research have shown that:

- a) two or more colours of dye can be developed, in sequence, when placed side by side.
- b) by mixing dyes, a change from one colour to another, by fading, can occur in the same position on the substrate. The strength of the colour of the dyes and their fading speeds determine the colours that are visible at any stage within this process.

c) a dye can be developed into one pattern and this can be changed into another, in the same position on the substrate.

Based on the parallels between the way that the shapes of the clouds move and change colour and the way that the dyes are able to be developed and change colour, clouds presented as a suitable reference for exploring the movement of the dyes to answer the project aim.

Their colours and placements as they progressively changed in the photographs was noted and simply illustrated. It was also noted that they were of any colour except green. As clouds that contain hail can appear light green this colour was not excluded at this stage. As stated in Section 8.2.3.2, the more texture within a cloud and the stronger its intensity of colour, the more emotive it appears. When the dye has just been developed, the dot mark is more defined and with a stronger intensity of colour than the fading dyes, therefore, it could be used to indicate a stronger atmosphere within the cloud-like shapes. For the dot mark to be used in this way, the order of some of the colour changes of the clouds was reversed. Next, to see if the realism of the clouds' colours could be matched with the colours of the photochromic dyes, these were mapped beside one another. However, as a slow fading dye could not fade into the colour of a fast fading dye and a faster fading dye could only disappear into a slower fading one if it was part of a mixed colour, this task did not provide any information that could be consistently used to inform colour choice. It did, however, reinforce the findings noted in Section 8.1.3, that is, that the use of these dyes will be dependent on placement and sequencing and this is determined by the colour of a dye and its' attached fading speed.

It was initially thought to develop two dyes in sequence when they were placed side by side, as stated in (a) above. However, the results of Section 8.2.4.1 showed that developing each colour sequentially with a column or with a block of light would show either columns of colour progressively fading into the substrate or a solid block of colour fading into the substrate. Both scenarios would still show one colour of dye beside another with a change of colour balance, depending upon the colours and fading speeds of the dyes used.

Method (c) describes the design sequence that had begun to be explored in Section 8.2.4.2. As the dyes, and consequently the colours, are not able to be moved from their anchored position, it was decided to create a variation of this. An alternative would be to move the image, via the light formation, from left to right. Therefore, a sequence was initially mapped out based on knowledge of the dyes' fading speeds and colours.

First cloud shape

A sequence was written to show a 'cloud' formation moving from left to right on the substrate. 'Palatinate Purple' dye was used based on the results of the iris technique, the intensity was set at 15, the time interval at 800ms. The lower time interval was used because the design was progressively being re-developed sideways. As the design was developed, the dye's fading speed meant that colour remained on the substrate as new colour appeared, resulting in the shape of the image being lost.

The faster fading 'Plum Red' dye, using the intensity of 10 and the time interval of 600ms, was then developed. This dye colour faded more quickly behind the lights and the developed shape could be seen more clearly. When the pattern speed was changed to 500ms the forward development was clearly faster but the progressive fading that helped to give the appearance of forward momentum also appeared as a dragging of the dye colour. Based on these results it was decided to re-develop the 'Palatinate Purple' dye using two second intervals to give it more time to fade. The intensity was set at 10. This resulted in a softer graduation to the dyes' fading (Fig. 8.19).

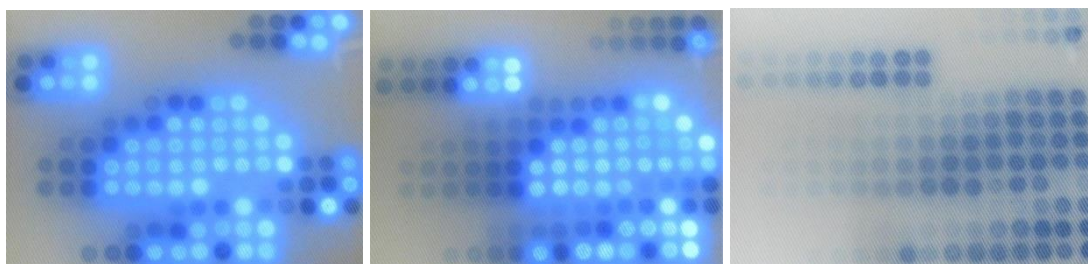


Fig. 8.19 'Palatinate Purple' dye (intensity 10 for 2000ms)

Based on these results, it was decided to re-develop the 'Plum Red' dye. As it is faster fading, the settings of intensity 15 and timing of 1500ms were used.

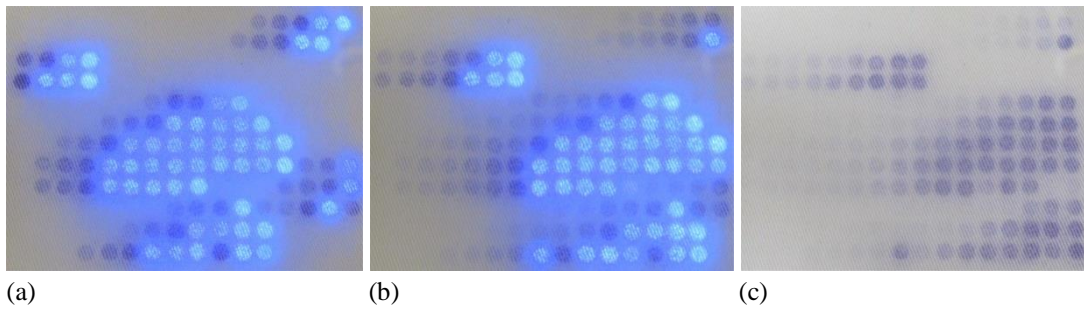


Fig. 8.20 'Plum Red' dye (intensity 15 for 1500ms) developing from left to right on the substrate

These settings enabled the 'Plum Red' dye to develop to a stronger intensity whilst also having a softer graduation of fading (Fig. 8.20). For both dyes the appearance of dragging decreased. This appeared to be a positive result. Although the aim was not necessarily to re-create clouds, at this stage learning to manage the dyes' fading was a step forward. Additionally, when the sequence was being developed it appeared as a group of lights in a cloud-like shape moving from left to right, with fading dye behind it (Figs. 8.20.a-8.20.b). It was noted that once the lights were turned off this defined shape was no longer visible (Fig. 8.20.c).

First cloud shape using mixed dyes

As the aim was to change from one colour to another, the mixed dyes of 'Flame' and 'Midnight Grey' were developed, with this design, to observe the appearance of slow fading dyes when developed in this way, as in method (b). Initial settings were unsuccessful. After reflecting on the results of the 'Flame' dye being developed in Section 7.4.2, this combination being developed in Section 8.2.4.3, and the outcome from developing the 'Palatinate Purple' and 'Plum Red' dyes at two second intervals, the settings of intensity 5 and the time interval of 1000ms were used. To allow the dyes time to fade, a space of 10 000ms was put between each development. This additional setting enabled the developed shapes to more closely resemble clouds (Fig. 8.21), however the similar fading speeds of the two dyes resulted in little visible change in the colour of the dots as they faded.

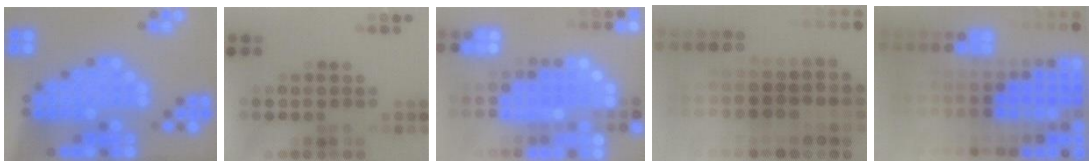


Fig. 8.21 Intermittent images of the 'Flame' and 'Midnight Grey' dye mix developed at 10 second intervals

First cloud shape beginning added

To more fully utilise the substrate, code was then written to extend this sequence at the beginning, as if to show the cloud shapes entering onto the ‘screen’ (Fig. 8.22). Based on the results of *First cloud shape*, the ‘Plum Red’ dye was used. The intensity was set at 15 and the development time at 1500ms. Based on the results of the ‘Flame’ and ‘Midnight Grey’ mix, a space of two seconds was used between each development.

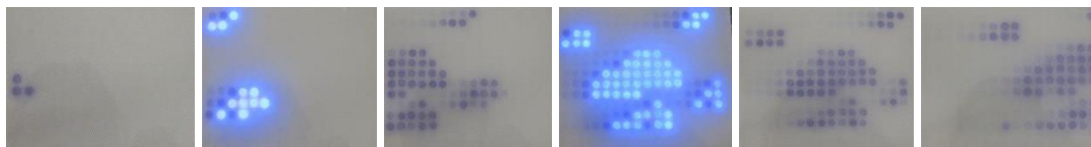


Fig. 8.22 Intermittent images of ‘Plum Red’ dye developed at intensity 15, development time of 1500ms at two second intervals

Developing the dyes so that the sequence appeared to enter onto the substrate was an effective way of showing its commencement, a sense of continuity and using the substrate more effectively. Also, placing the two second interval between the re-developing dye gave the shapes considerably more definition than when they were developed in *First cloud shape*. The combination of the more defined image and the longer sequence showed how a narrative, in the more traditional sense of a moving image, may be able to be built. Therefore, based on the results, it was decided to explore changing this more defined image as it moved across the substrate.

Changing cloud shape

Code was written for another cloud formation with the aim of showing it progressively changing shape as it was being developed from left to right. When the sequence had finished on the right hand side, another sequence began developing the dye from the left hand side to further explore showing a sense of continuity. Based on the above results, ‘Plum Red’ dye and the same settings as above were used.

The small size of the cloud-like shapes made them appear as a collection of scattered dots on the substrate, indicating that when developing the dyes with the LEDs at this scale, a shape that had a degree of recognisability was needed (although, of course, ultimately it would depend upon the purpose of the design). The changing cloud shape sequence did, though, show that re-developing the dyes with a sequence from the left side of the substrate would be an effective way of illustrating continuity. Based on these results, it was decided to continue using the design from the *First cloud shape* at this stage.

First cloud shape beginning added using mixed dyes

As the initial exploration of using mixed dyes in this design sequence used two slow fading dyes, it was decided to explore other dye combinations.

The colours of ‘Corn Yellow’ and ‘Plum Red’ dyes are from opposite ends of the fading spectrum and on opposite sides of the colour wheel. To note their fading pattern, they were first developed by a single light column moving from left to right. Based on the results of *First cloud shape using mixed dyes* the intensity was set at 5 and the development time at 1000.

This combination of dyes initially developed to a shade of brown. As the ‘Plum Red’ dye faded, the colour on the substrate progressively changed to yellow. As the developed colours were pale and ‘Corn Yellow’ is a slightly faster fading and more lightly coloured dye than ‘Flame’, this mix was re-developed for two seconds, resulting in an increase in colour intensity that enabled the colour change to be more clearly seen (Fig. 8.23).

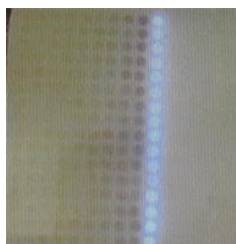


Fig. 8.23 ‘Corn Yellow’ and ‘Plum Red’ dyes developed for two seconds by single light column

The dyes were then developed using *First cloud shape beginning added*. Based on the results of *First cloud shape using mixed dyes*, a space of 10 000ms was put between each development.

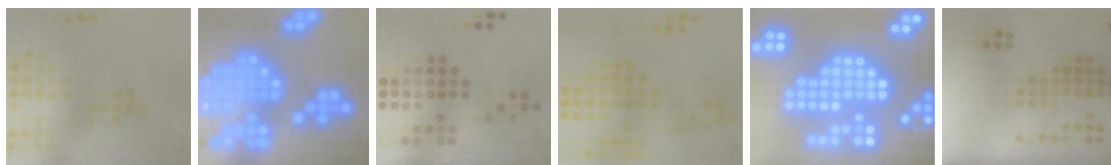


Fig. 8.24 Intermittent images of ‘Corn Yellow’ and ‘Plum Red’ dyes developed at intensity 5, development time of 2000ms at 10 second intervals

Using this combination of dyes, with contrasting colours and fading speeds, a colour change was very effectively able to be illustrated, with the sequence showing the dyes fading from one colour to another within the same position (Fig. 8.24). It also showed

how the dyes appear when re-developed side by side. Their progressive fading, when developed in this way, gave the appearance of clouds moving sideways and changing from one colour to another.

As 'Flame' and 'Plum Red' dyes have contrasting colours and fading speeds, they were also developed with the single light column to note their fading pattern. Based on the above results, the intensity was initially set at 5 and the development time at 1000. This resulted in the initial appearance of a purple/brown colour that, as the 'Plum Red' dye faded, progressively changed to dull orange. To increase the strength of their colours, the dyes were then re-developed for 2000ms. This resulted in stronger colour development that subsequently gave clearer definition to the dyes' fading.

The latter settings of intensity 5 and time interval of 2000ms were then used to develop the *First cloud shape beginning added*. A space of 10 000ms was put between each development. These settings enabled the dyes' initial colour development and change, as they faded, to be seen clearly (Fig. 8.25).

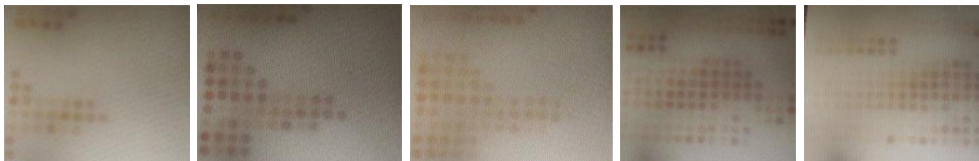
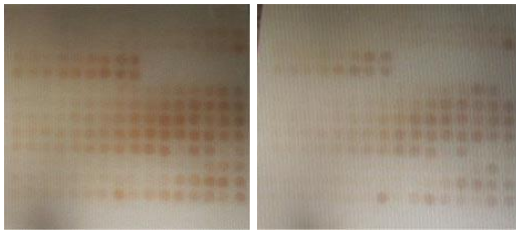


Fig. 8.25 Intermittent images of 'Flame' and 'Plum Red' dyes developed at intensity 5, development time of 2000ms at 10 second intervals

Although the intention was not to create an exact replica of clouds, exploring the effect that development times and intervals had on the shapes that were developed would further inform design development. Therefore, it was decided to re-develop this sequence for 1000ms. Although the colour would not be as strong, the aim was to decrease the appearance of the drag effect the fading dyes created behind those that were being developed.

Comparing the two sequences, it was noticeable that the cumulative effect of the two second development time, that gave the dyes more time to fade, resulted in a cleaner, more defined image (Figs. 8.26.a-8.26.b).



(a)

(b)

Fig. 8.26 a. 'Flame' and 'Plum Red' dyes developed at intensity 5 for 1000ms at 10 second intervals

b. 'Flame' and 'Plum Red' dyes developed at intensity 5 for 2000ms at 10 second intervals

When each pair of mixed dyes faded, the slower fading dye remained visible on the substrate. Both pairs of colours initially developed into a shade of brown, a colour that may be associated with sadness. They then faded to either yellow or apricot, both of which may be considered to represent joy. Therefore, a colour change, from one that represents sadness to another that represents joy, has been able to be achieved.

The cloud-like shapes moving from left to right show how the dyes are able to develop an image that appears to be moving sideways. Although, in this instance, the same image was used, the sequence illustrates how it could also change and this could be done in several ways:

- it may appear to be changing position, like a flower growing from seed, blooming then withering and dying.
- the image could slowly morph into a completely different image by way of changing shape progressively as it was developed from left to right.
- a completely different image could appear in each consecutive development.

One colour could be used in each of these sequences and each of these changes of image could potentially be used to tell a narrative. If the fading of two dyes was used, this would show a change of colour and the shape of each development would determine what the viewer saw with each image change. However, the success of each of these sequences would be based on the development times and intervals used.

The sequencing could also occur in another way, as a further step when exploring the dyes' mimicking of the placement and development of the colours of the kaleidoscope. For example, different colours of dye, printed on different parts of the substrate, could be developed consecutively, in different shapes, to tell another 'story' that is made up of pictures. The light patterns may develop the image all at once, in the same position, or the image may be developed by a column of lights, moving from, e.g., left to right, to

give it a different sort of fleeting appearance, still within the same position. There would still be ‘fast’ and ‘slow’ pockets of colour, however, varying the image and its size, and the sequences within which these were developed, could also create designs that could create narratives using more than one or two colours. This exploration, however, would take much more time than this research permits, therefore the resulting interactions and effects that using the dyes in these sequences could potentially create, and the subsequent narrative created, could be explored in future work.

Although a colour change within a moving image has effectively been shown, it did not appear that this design evoked an emotional response in the viewer, or indeed, moved the viewer from one emotion to another. If, like Rothko’s paintings, the colours were shown on a larger scale, the development and re-development of the dyes, for appropriate amounts of time and at appropriate intervals of time, to create a hovering effect, may create an emotive piece of work. Using a larger canvas may also enable the subtle differences that can be seen in the dyes’ colours and the colour changes as they fade, as also illustrated with the ‘Sea Green’ and ‘Volcanic Grey’ stripes in Section 8.2.4.1, both individually and mixed, to be better seen, better explored and perhaps felt. Therefore, exploring the dyes in this way, on a larger scale, would be an interesting area for future work.

The sequencing of the dyes’ development from left to right, using the cloud-like shapes, enabled the dyes’ colours as they progressively faded side by side to be clearly seen. These shapes were also able to illustrate how development time affects the effect created by the amount of colour that is visible at different stages of the dyes’ fading. For example, the dyes may be used effectively to show slowly moving clouds however their shape was lost when developing the dyes at shorter intervals to give the appearance of the shapes moving more quickly across the substrate. These observations indicate that combining different development times (both how long a dye is developed and the intervals in between their development) with different depths of shade of the dyes’ colours would be a worthwhile area of design development to explore in future work.

Tension and time

It was shown in Section 7.4.1 that, depending upon the frequency with which the dyes were successively developed, subtle differences in tension were illustrated and it may be through creating contrast with this effect that a change in feeling in the viewer is able to

be felt. Where on the emotional spectrum this sits, whether from joy to sadness or somewhere in between, would be determined by the colours, their placement, sequencing of development and development times. The results so far also indicate that the aspect of time, an inherent part of the movement of these dyes, and an important part of their narrative, may need to be drawn out over a longer period and this will be taken into consideration within subsequent designs.

It was initially thought that clouds, with their diversity of colours and direction of movement that, in principle, would be able to be replicated by the dyes, would be a way of showing a change from one colour and emotion to another. It was also thought that their shapes, that are basically large masses of colour that could be represented abstractly, would enable the movement of the dyes to be focussed upon. Although they have been able to effectively show a colour change, the scope for further exploration of the dyes' movement to create variations in tension was limited. Therefore, by reflecting on the design tests so far, and the narrative effects noted in Section 8.2.1, it was considered that the development of a sequence of changing images would be a way of exploring a change in tension.

As a fading dot would be used to build the imagery, Hodgkin's mark making was reflected upon. Although like Rothko, he used a still medium and his paintings were not pictorial, the representational abstract forms he created led to a degree of recognition in the viewer that was able to evoke an emotional response.

Developing the dyes on a larger scale, as in Sections 7.4.1 and 7.4.2, effectively illustrated their colours and fading patterns and, as previously stated, would provide a larger canvas for the dyes' exploration. However, due to the time available and to place the focus on the way the dyes move and interact together (rather than spending time managing software), it was decided to explore their ability to create a visual narrative, utilising the programmable array that had been built. The results of this work could then be explored further within a larger design in future work. The Flash programme would be useful for trialing any larger scale of design to see how it appeared before building another larger sized array.

8.2.4.5 *Sea lapping shore*

The Reversacol dyes used for testing were:

‘Flame’  : ‘Palatinate
Purple’ 

The aim of the project has been to capture and express emotion to reveal the form of narrative that the dyes are able to communicate. Using the colour parameters that were set, the cloud-like shapes have been able to show a change from one colour to another, in those that may be associated with joy and sadness. Although if that direction of design development was explored further at a larger scale it may be able to evoke a change in emotion in the viewer, it was decided to further explore the element of tension that the dyes’ movement is able to create. A change in tension may also carry the viewer through a change in emotion.

Based on knowledge of the dyes that had accumulated, it was decided to use two colours, from opposite ends of the colour and fading spectrums, to develop this sequence. It was noted in Section 7.4.2, that the visual effect of the fade back pattern of the faster fading ‘Palatinate Purple’ dye gave a more horizontal sense of movement, whereas the ‘Flame’ dye appeared to move in a more vertical manner. The image ‘Evening Reflections’ (Fig. 8.27) with its varying shades of orange and blue, reminiscent of the sand and the sea (Fig. 8.28), provided inspiration for ways of further exploring the dyes’ movement.



Fig. 8.27 ‘Evening Reflections’ [8.9]



Fig. 8.28 Rainbow Beach [8.10]

The colour and fading speed of ‘Palatinate Purple’ could be used to illustrate water moving towards and retreating from the shore. A balance may be able to be found between the dye giving a sense of forward movement and the opposing dragging effect that it can create. The orange coloured ‘Flame’ dye could be used to represent the sand. Its slower fading speed would make it visible for longer, providing a sense of permanence against which the faster fading blue dye could be contrasted. Developing

the dyes alternately would be a way of exploring the creation of different degrees of tension.

Development of sequences

A range of ways of using the stylistic techniques, by applying different speeds of development and developing the dyes to different intensities, were considered in combination with the narrative effects and sequences highlighted in *Design Planning 2* and *2a*. The representation of simple objects easily associated with the sand and sea, such as shells and fish, was also considered. A series of sequences was designed to incorporate these features.

A peaceful scene was initially set with the sun rising, waves lapping the shore, a sea shell on the sand and a small fish in the water. This was followed by a change in tension illustrated by an increase in the speed of the waves and the gradual introduction of a shark fin approaching the shore. Its presence caused the small fish to become 'alarmed', illustrated by it changing position quickly and repetitively in the water. Calmness was restored by the shark fin moving away from the shore, gentle waves, the small fish 'swimming' more slowly, another shell developing on the sand and the moon rising in the sky.

After initially planning these sequences in black and white, they were sketched in blue and orange, to represent each dye, to visually note the frequency with which each colour appeared on the substrate. After each image was mapped on the array template, the code was written and then tested by developing the dyes, making any necessary alterations to increase the image's recognisability. Either a curved or an angular iris technique was developed, to indicate that a change in atmosphere was to follow, on the same side of the substrate on which that iris technique was developed. Several images were then developed in sequence, noting the tension, fading speeds and overall effect that was being created.

The results of the dyes' development and fading in the *Clouds* sequences informed initial settings and these were then adjusted with the aim of maximising the contrast in the rhythm created. These were made in the form of decreasing or increasing the intensity, development times and development intervals. The length of each sequence

ranged from 81-120 iterations. Knowledge learned from the initial sequence informed the next one, and so on, and enabled adjustments to be made to the larger narrative.

Each section of sequences was photographed and storyboarded, enabling an overview of the effect created and the amount of colour of each dye that was visible in each section to be seen, although it had to be remembered that the dye was constantly fading whilst the photographs were being taken. Although the Perspex cover of the array protected it from ambient light and did not alter the development of the dyes, the reflection that it caused, hindered by its larger size, when filming and photographing the dyes, makes the dyes appear less bright than they are in reality, however both means of recording contributed positively to the design and research processes.

Although this custom-made array has been invaluable for exploring the dyes in a controlled manner, its capacity for continual repetitive use had not been tested. Therefore, advice from the hardware engineers was heeded and caution was taken with the number of iterations and duration of each light sequence.

Sequence A

The aim of this sequence was to establish a calm scene, hence the imagery and development times used. Both dyes were developed to show their colours on the substrate (Fig. 8.29.a). A soft iris technique developing inwards was initially used to open the scene and draw attention to the left side of the substrate (Fig. 8.29.b). An individual orange dot was used to represent the sun as it rose from the bottom left of the substrate towards, what could be seen as, the blue of the sky. A 'soft' iris technique (Fig. 8.29.d) was used to indicate that a change in 'scene' was to occur and it would be on the 'Palatinate Purple' side of the substrate. The intensity of colour and development times of the iris techniques were mainly decreased so they didn't take so long to fade.

Three waves (Fig. 8.29.e-g), mimicking one of the iris techniques, were developed in succession. Initially the second and third waves were re-developed whilst the previous ones were fading. However, to show the difference in appearance created by the amount of time they were developed, a larger interval was placed between their development, enabling the difference in their fading speeds and intensity of colour to be illustrated, although this was subtle.

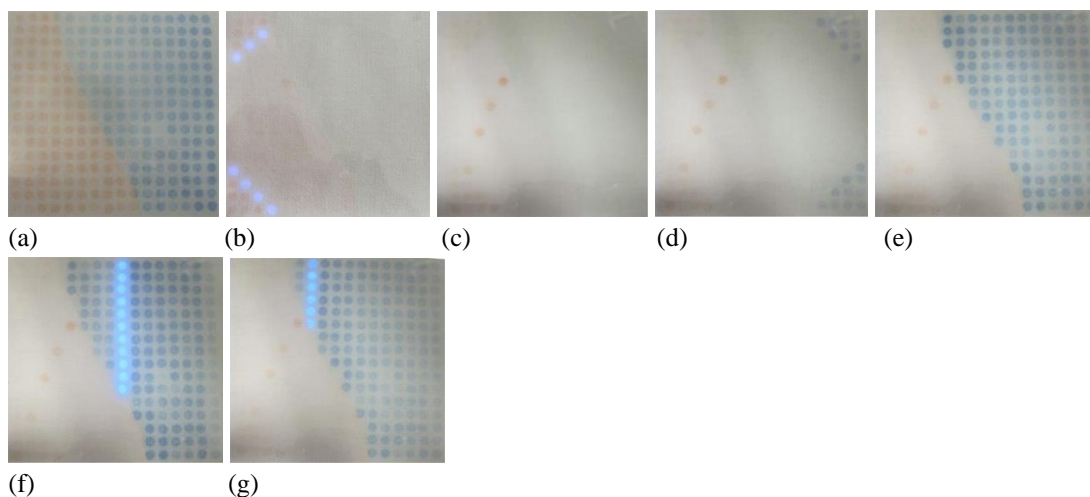


Fig. 8.29 Section A of storyboard sequence

- a. 'Flame' and 'Palatinate Purple' dyes developed to show their placement
- b. soft iris technique on left-hand side
- c. the sun rising
- d. the iris technique on right-hand side
- e-g. three waves at different tensions

The dyes were being developed by a current of 20mA. If they were developed by more high powered LEDs, the greater difference in colour intensities (as illustrated in Section 5.7.2.2) could be used to more clearly represent different depths of water. Their intervals of development were decreased to show a lighter strength of colour representing shallower and faster waves. This also made the 'waves' fade more quickly.

As the sequence developed, other elements that can be used to construct a narrative were revealed. For example, the slow fading of the 'Flame' coloured sun (Fig. 8.29.c), initially appeared as a hindrance, necessitating larger intervals to be placed between it and the development of the 'Palatinate Purple' dye that represented the three waves (Fig. 8.29.e-g). However, the presence of the sun as the waves were re-developed may represent the continuation of time from morning till noon. Nuances such as this may not be obviously apparent to the observer however it is these subtleties that contribute to the making of a story.

The pale green residual colour of the 'Palatinate Purple' dye could be seen on the substrate. In this design, its presence could be considered inconsequential, as it could be associated with shallow sea water.

Sequence B

This sequence commenced with a soft 'Flame' iris technique (Fig. 8.30.a-8.30.b) to introduce the viewer to the development of a 'shell' on the sand (Fig. 8.30.c). The 'sand' was also referenced by the colour of the shell. A soft 'Palatinate Purple' iris technique (Fig. 8.30.d) indicated that something was about to happen on the 'water' side of the substrate. Three waves (Fig. 8.30.e-g) were developed in succession, at different intensities, speeds of development and starting placements as a way of indicating depth. The 'shell', developed by the 'Flame' dye, remained visible while the waves were lapping the shore, again referencing time by its continued placement on the sand.

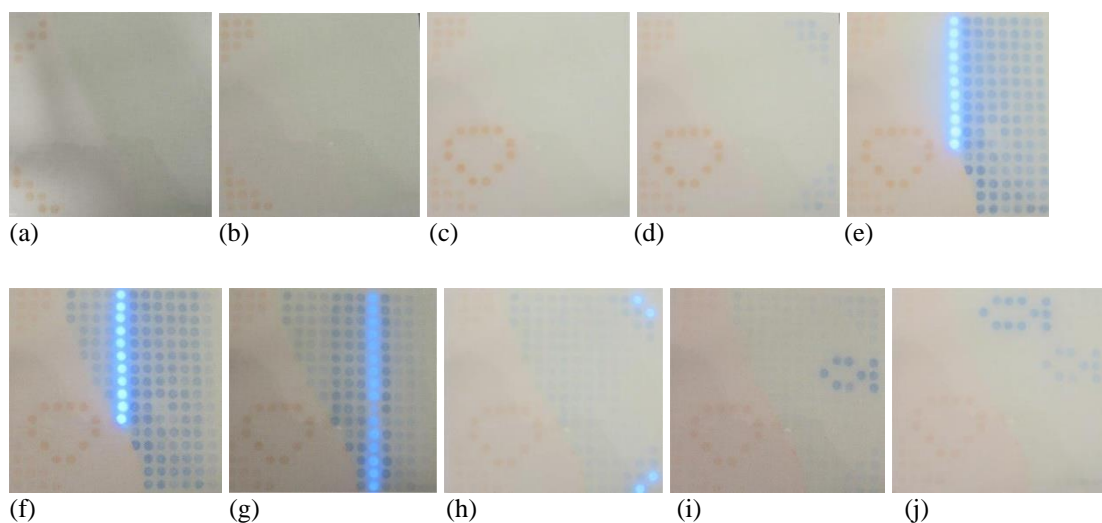


Fig. 8.30 Section B of storyboard sequence
a-b. soft iris technique

c. shell

d. soft iris technique on right-hand side

e-g. three waves at different tensions

h. soft iris technique on right-hand side

i-j. small fish 'swimming' to left

The waves were followed by another soft 'Palatinate Purple' iris technique (Fig. 8.30.h). A small fish appeared on the substrate (Fig. 8.30.i). Its movement was illustrated by a change in position, increase in size and an increase in colour intensity (Fig. 8.30.j).

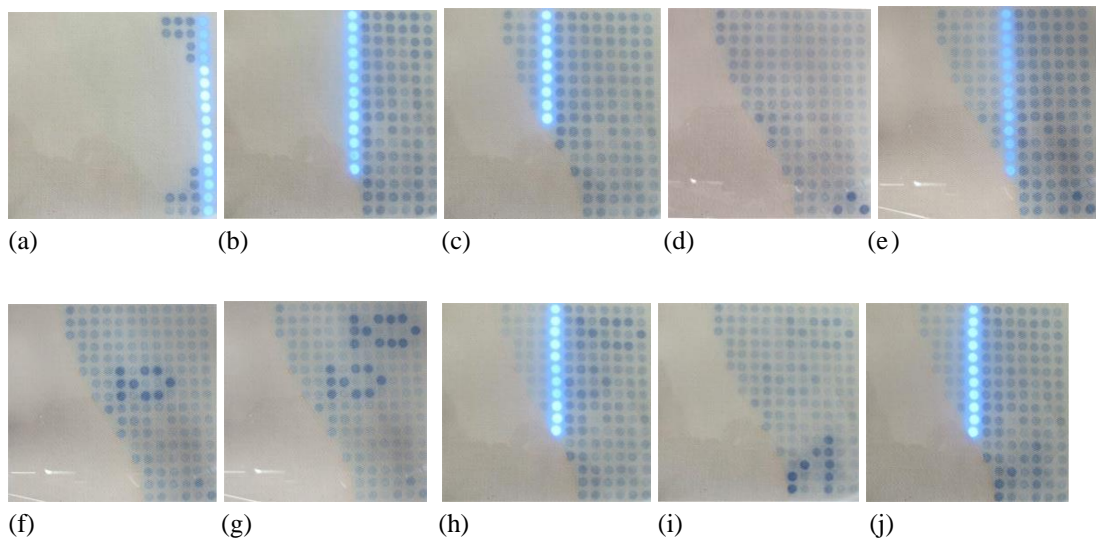
A series of waves, initially placed between the iris technique (Fig. 8.30.h) and the small fish (Fig. 8.30.i), was removed from the sequence, as it was considered that a sense of

calmness had sufficiently been represented by the time period that had been alluded to, the imagery used and its speed of development and fading.

Sequence C

The square iris technique (Fig. 8.31.a) was used as a forewarning to indicate that a change in atmosphere, to one more ominous, was to occur in the next scene. Two waves (Fig. 8.31.b-c) were developed for shorter time periods to increase the sense of tension. A simple shape was used to represent a shark's fin (Fig. 8.31.d) in the distance. A single wave was developed quickly towards the shore (Fig. 8.31.e) to illustrate an increase in tension. It was developed over the fin in a way reminiscent of the superimposition film technique. The little fish was shown (Fig. 8.31.f-g) 'swimming' away from the shore (and towards the shark). Another fast wave was developed (Fig. 8.31.h). The shark's fin was now closer to the shore (Fig. 8.31.i). The placement of the fading imprint of the fish could be seen as illustrating another fish or two in the water or as a reminder that it was present. Another wave passed quickly (Fig. 8.31.j). Figures 8.31 (k) and 8.31 (l) are to illustrate the little fish in a frenzy, darting backward and forwards, changing direction quickly and repetitively, in the same place on the substrate.

The frenzied fish at the end of Sequence C (Fig. 8.31.l) and the large shark's fin at the beginning of Sequence D (Fig. 8.32.a) will appear on the substrate together, another representation of superimposition. As the shark's fin is larger and darker in colour than the fish, fading behind it, the shark could be seen as 'swallowing up' the little fish.



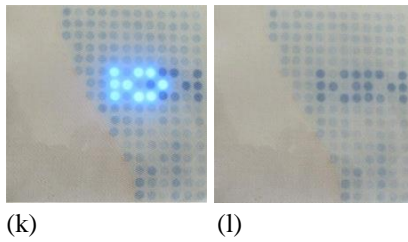


Fig. 8.31 Section C of storyboard sequence

- a. square iris technique
- b-c. two faster waves
- d. small shark fin
- e. single faster wave
- f-g. small fish 'swimming' in direction of shark
- h. single fast wave
- i. medium sized shark fin
- j. single fast wave
- k-l. small fish developed to face left, right, left, right

Sequence D

The shark's fin was shown to increase in size (Fig. 8.32.a). This was then followed by three slow waves (Fig. 8.32.b-d). The fin was then shown to have turned away from the shore and decreased in size (Fig. 8.32.e). This was followed by three slow waves (Fig. 8.32.f-h) and a smaller fin (Fig. 8.32.i). A soft iris technique developed outwards to illustrate a change in the 'scene' (Fig. 8.32.j). Two slow waves were then developed from left to right (Fig. 8.32.l-m) and the little fish could be seen swimming again.

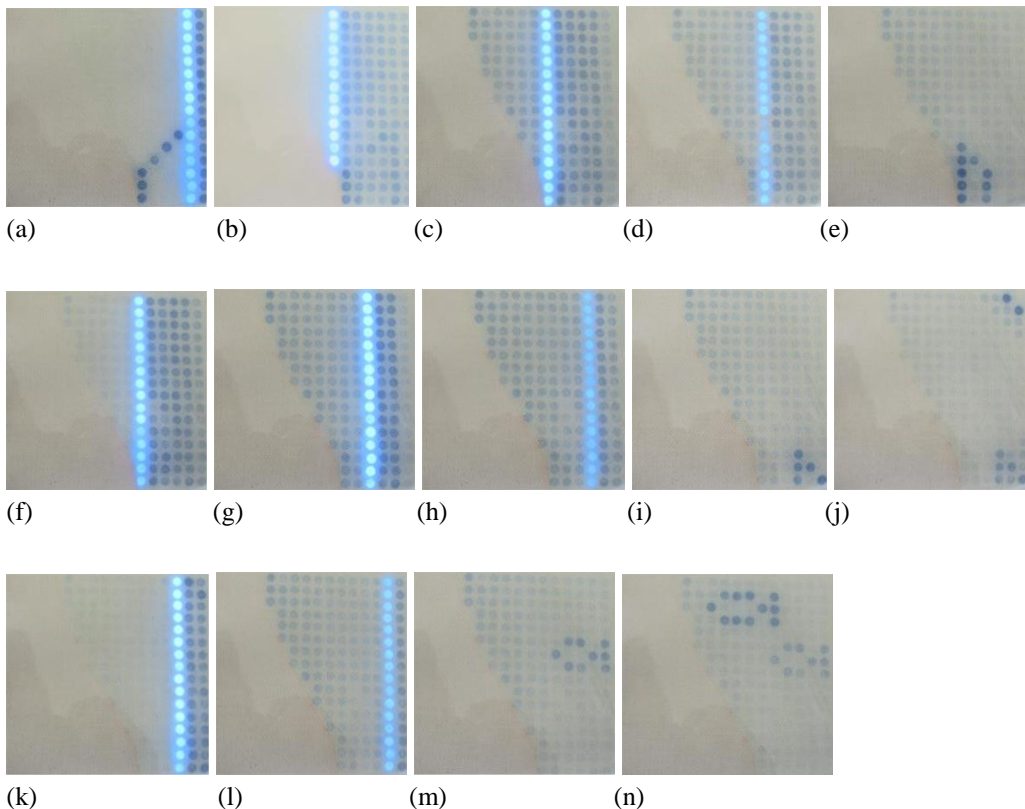


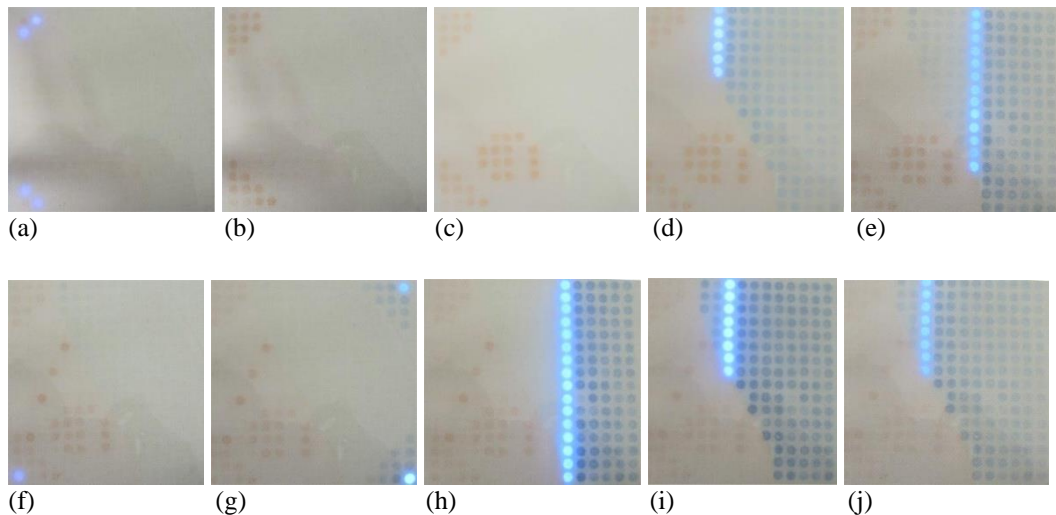
Fig. 8.32 Section D of storyboard sequence

- a. small shark fin facing the shore
- b-d.. three slow waves
- e. medium shark fin facing out to sea
- f-h three slow waves
- i. small shark fin facing out to sea
- j. soft iris technique
- k-l. two slow waves
- m-n. little fish swimming

The development of the large shark's fin facing the shore (Fig. 8.32.a) followed by the three slow waves (Fig. 8.32.b-d) and the shark's fin, smaller in size and facing out to sea (Fig. 8.32.e) was to create a sense of uncertainty in the viewer. What happened? Was the little fish eaten by the shark? This uncertainty was answered, or not, by Figures. 8.32. m and n. We don't know if that is the same little fish or another little fish.

Sequence E

This sequence began with a soft 'Flame' iris technique (Fig. 8.33.a-b) to introduce a different shape of 'shell' (Fig. 8.33.c). The dot mark and the LEDs were also able to be used in another way. The progressive development of the shell, in a spiral, was also used to draw attention to its coiled shape and to potentially allude to a celebration after the 'shark' had swum away. It may hint at fireworks or the development of psychedelic patterns, both of which are bright and cheerful. It could be seen as a celebration because the little fish escaped or because it is a new moment, a new beginning. Its slow fading could again be used to represent time, as the 'shell' remained on the substrate while more waves were re-developed (Fig. 8.33.d-e), this time at a lower intensity of colour. Their repetitive re-development also contributed to the notion of time.





(k)

Fig. 8.33 Section E of storyboard sequence

- a-b. soft iris technique
- c. shell developed in circular formation with single light
- d-e. two waves at different tensions
- f. sun going down
- g. soft iris technique
- h-j. three waves at different tensions
- k. moon rising

As the 'Flame' iris technique (Fig. 8.33.a) had still not faded it was not re-developed to introduce a new scene on the left side of the substrate where the single dot mark was again used to represent the sun, this time as it set (Fig. 8.33.f). It began beside the water and disappeared into the corner of the substrate. The slowly fading shell was still visible on the sand. This may be used to again represent the passage of time in a peaceful way without disturbance, however its lack of definition, caused by the fading dye could also be seen as messy. A soft 'Palatinate Purple' iris technique (Fig. 8.33.g) developing outwards, was used to represent moving away from something, perhaps the day, after the sun had set. Three more peaceful waves moved towards the shore (Fig. 8.33.h-j) before individual dots of 'Palatinate Purple' dye were used to represent the 'moon' rising alone in the sky (Fig. 8.33.k). No more techniques were used to emphasise the finality of the last 'scene'. However, both the 'Flame' and the 'Palatinate Purple' dye may have been developed by single columns of light, at the same time, moving towards the centre of the 'screen', to represent curtains being drawn, ie., THE END.

Elements used to create sequence

When observed as one overall sequence, it has been shown how, by using a combination of depth of colour, imagery, altered placement, and variation of development times, intervals and speed of development of the dyes, a visual narrative is able to be created. This sequence was used to represent a change in atmosphere, a mixture of feelings created – apprehension, fear, sadness, relief, joy - by increasing and decreasing the sense of tension by combining these elements. Its affect was limited within this sequence, due to the scale of the work. The concept, however, has been

illustrated and further development on a larger scale may be able to show how these elements of design could create a narrative that would be able to evoke a change of emotion in the viewer.

Mark making and imagery

The simple representational shapes, using outlines or single dots were used to illustrate the concept of how these dyes can be developed to create imagery. Certainly if the size of the substrate was larger, the dots would be able to create more figurative imagery. On a larger scale the definition of shapes made would be smoother as the size of the dots in proportion to the substrate would be smaller, as illustrated in Figure 34. Although the development of a small motif on a white background contributed to the colours looking duller and lighter than they were, the space created also led to a sense of anticipation of what was going to appear next on the substrate.

Stylistic techniques

The stylistic techniques have enabled the practical capabilities of the dyes, when they are applied to the textile substrate, to be ascertained. Their adaptation to create representational imagery and as transitional techniques has been constructive. Their use on this scale has illustrated how they appear when used as a configuration for developing photochromic dyes. They also show the potential to assist with the expression of feelings within the creation of a narrative if used on a larger scale.

The iris techniques have been used to represent a change of 'scene' although their use was linked with how long they took to fade. They could be left out of the sequence however they do help to frame the scenes. The technique of superimposition was re-created in Section C (Figs 8.31.e and 8.31.j).

The fading of the dyes, to represent waves, did not appear to be 'dragging' when used in this way. Their arrangement could also be used in other directions on the substrate however, as noted in Section 8.2.4.3, its rhythm would be affected, and interrupted, by any other dye and its placement within the design. Using only a single colour on the substrate would enable a range of iris techniques to be fully developed and the placement of any representational imagery would be either more defined or less defined by that dye's colour, if creating a narrative, depending upon the 'story'. As the aim of this project was to explore narrative showing a change of emotion using a change in the dyes' colours, this avenue was not explored.

Fading and movement

As the dyes move as they fade, rhythmic editing, used in French Impressionist films, is already an inherent part of their composition. This can be managed by controlling and staggering the dyes' development time, enabling a sense of anticipation to be created, with the expectation that something else, e.g., in the form of the appearance of a colour, somewhere else on the substrate. Sequence E, (Figs. 8.33.f and 8.33.g), illustrated that a balance needs to be found between how much of one colour/image remains visible on the substrate before another image is developed, highlighting that it is necessary to manage how long the dyes are developed and the time intervals between their development.

Proportion and placement of dyes

The fading speed of the two dyes influenced the proportion in which they covered the substrate. Their placement and colour then influenced their development. For this reason the amount of 'Flame', as the slower fading dye, on the substrate was considered. Leaving it to fade completely before another image was developed would mean there was at times very little colour on the substrate so again, a balance needs to be found as this also affects the overall movement within the sequence.

Tension

The element of tension and how it can be changed was explored and represented by

- developing the 'Palatinate Purple' dye with a single light column both quickly and slowly to mimic waves lapping the shore
- the image of a shark fin changing in both size and placement
- altering the spaces between the development of the dyes
- the more peaceful 'scenes' developed on the 'Flame' sand contrasting with the more active ones created in the faster fading 'Palatinate Purple' water.

Even though the above techniques were used the creation of a change in tension was limited. As commented in Sequence A, developing the dyes with more high powered LEDs, the greater difference in colour intensities may create the contrast needed when the dyes are used on a larger scale.

Temporal dimension

Inherently, there is a temporal dimension to any image created with photochromic dyes. Their individual fading speed means that their appearance on the substrate changes

either quickly or slowly, and this determines the amount of time an image is visible. The image alters depending upon how much the dyes have faded, thereby impacting on any narrative created by the sense of continuity that is created and the expectation for something else to occur.

Strength of colour

The strength of the dyes' colours, when developed by the artificial UV light, was sufficient for creating designs to explore the interactions of their colours and movement. It also enabled their intensity to be varied which then created a change in the fading times. Progressively changing the dyes' intensity was able to demonstrate how this can be used to change the impact of any image created.

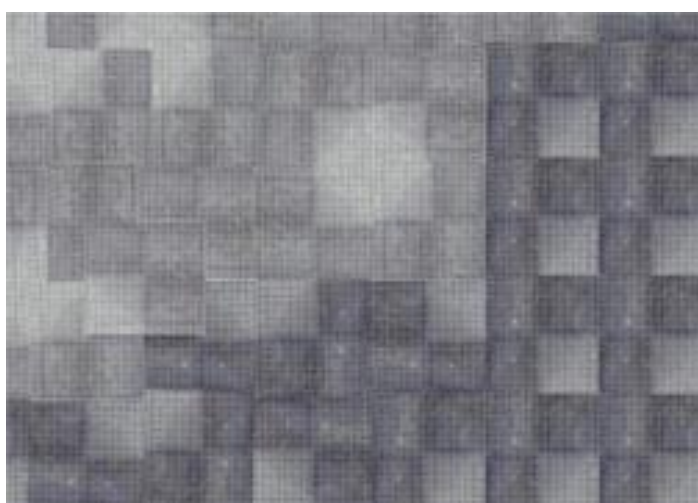


Fig. 8.34 Illustration of size of substrate if 6 x 4 arrays used

Figure 8.34 illustrates how the dot mark would appear if the dyes were developed on a larger canvas of approximately 6 x 4 arrays. The softness of dyes developed at a lighter intensity contrasted with those developed at the higher intensities is able to be seen. It also shows how the dot motif could be used to create more figurative imagery if used on a larger scale.

The lights

As large areas of dye were not being developed at the same time and representational imagery was being used, the lights did not appear to be the focus of, or detract from, the development of this design. They were a part of it and it was clear that dye would appear on the substrate in the place where a light had appeared.

8.2.5 *Visual narratives and communicative textiles*

The work in this thesis has shown how photochromic dyes have the potential to create a visual narrative when they are applied to the textile substrate. As stated by Barry, ‘stories live in and are influenced by their container, the medium of their telling’ [8.11]. The exploration of this relatively new technology illustrates how sequencing is the guiding factor to their application within any design created.

According to Andrew, a visual narrative is ‘a story or message that can be expressed by images without the use of words. This usually needs figurative imagery arranged in some type of sequential form’ [8.12]. Although this definition may generally be applied to the more traditional static imagery used on textiles, the *Sea lapping shore* sequence shows the potential for photochromic dyes to tell a ‘story’, by combining elements of design such as placement, proportion, colour and sequencing with one another. The dyes’ moveable quality enables, for example, the position of the representational image of the shark’s fin to be moved on the substrate, as well as increased in size and intensity of colour. When this was combined with varying the intervals between the dyes’ development, the potential for an increased sense of tension, if the dyes were used on a larger scale, has been illustrated. As the intensity, size, position and duration of each of these elements is able to be altered, so is the rhythm of the narrative that they would collectively create. As the dyes are able to be developed into different shapes they have the capacity to create a diverse range of imagery that could be combined to tell a story.

The *Sea lapping shore* sequence had different images visible at different times, as they were developed one after the other. Depending upon the intervals between each image, they may be seen in isolation by someone observing the sequence in passing. Therefore, Andrew’s statement, that ‘a single work can also create a visual narrative through one ‘picture’’, also brought to mind that the interpretation the viewer may have of an individual image, observed in isolation, may be entirely different from how they would interpret the whole ‘story’ if the images were observed as part of a sequence.

The *Clouds* sequence has shown how the dyes are able to create an image that appears to be moving sideways, also incorporating a change of colour. The re-development of imagery, from the left hand side of the substrate, shows how the length of a sequence could be unconstrained by the size of the array providing scope for the development of a

longer linear narrative, as opposed to the dyes' alternate development in *Sea lapping shore*.

Barry also states, 'as new containers are invented, the activity of story construction, for that particular container, evolves as users find creative ways to express themselves within a new medium' [8.13]. The concept behind the *Tree, bug and planet* design provides a way of exploring the dyes' sequencing further and to potentially push the boundaries of representing what is familiar to us with colours that do not usually illustrate a particular object. Different colours, based on their hue and their fading speed, would be brought to the fore and another understanding of the way a narrative is able to be created has the potential to be revealed. The ephemeral nature of these dyes would also add to the delay in recognition of something that would ordinarily be more easily identified. For example, Re-creating the *Sea lapping shore* sequence using 'Corn Yellow' and 'Plum Red' dyes would provide another starting point for using the dyes' colours in this way. Their opposite fading speeds may, incidentally, give more contrast and therefore more definition to this sequence.

Andrews also states, 'communicative textiles don't necessarily have to be visual narratives, they could communicate meaning based on their form, colour or material, evoking a more emotive reaction based on associations with other objects or experiences (which may be personal experiences or 'culturally learned' reactions). So the communicative capacity of a textile (as with other works of art or design) is controlled to some extent by factors outside the object itself. Context, culturally learned responses and responses based on personal experiences all inform a viewer's reading of the work, so the meaning the maker encodes in the work, through images, colour, materials, processes of making and form, may only communicate part of the intended meaning to the viewer.' [8.14].

Accordingly, the *Clouds* sequence has shown that the dyes, when printed on a fabric substrate, enable this material to be classified as a communicative textile. For the aims of this project, a colour change from brown to yellow and brown to orange was illustrated. As previously stated, if they were developed on a larger scale of substrate, and their development and re-development was further explored, they show the potential for evoking certain feelings in a viewer. However, clouds do not usually appear brown. Although they may appear yellow as part of a sunset, they do not usually

fade from brown to yellow or from brown to orange. Clouds of smoke may appear brown and sunrises and sunsets may appear yellow and orange. Therefore this design, developed on a larger scale, and the dyes' development explored to create different shapes, shades of colour and variations in the rhythm of movement of the colours, may elicit recollections of bushfires in a viewer, illustrating another way that these dyes may be used to create a communicative textile. Likewise, a change from one colour to another, using dyes from other parts of the palette, may also evoke emotive responses in a viewer, signifying entirely different things to different people.

The transience of these dyes means they are able to create a design that literally shifts between being one that is considered a printed textile design and an ephemeral moving picture. If technological research enabled their physical properties to be improved so they were able to sustain an appropriate life span, the development of moving imagery, using this medium, on a textile substrate, would fit comfortably amongst the contemporary design discussed in the literature review. The dyes' ability to move combined with the bright lights of the LEDs, may also place this work within the category of lumino kinetic art, the existing subset of kinetic art [8.15].

8.2.6 *A conceptual product*

People want to enjoy the benefits of the latest technology, while not losing any of the traditional values associated with home life [8.16]. Some find new technologies daunting and an ugly intrusion into the domestic environment [8.17]. It has been stated that when combining computational technology with a material such as a textile, it is important to find a way between, on the one hand, just using the textiles to re-invent existing interaction devices in a new material, and, on the other, simply enliven certain textile artefacts using more technology [8.18]. Accordingly, the intention of this conceptual product has been to enhance the domestic environment into which it would be placed. Instead of a still painting, a warm, poetic piece of design work could help in the creation of an inviting ambient space, with the aim of satisfying the need identified by Stefano Marzano, 'If we're to make the quantum leap from the limited materialistic and quantitative market to the unlimited, more spiritual and qualitative market, then we must provide the design worthy of it.' [8.19] With the added dimension of movement there is the potential for these dyes to create more than a flat image made up of dabs of colour.

Krippendorff has stated, 'Inquiries that could inform design practices would have to start by acknowledging the simple fact that design is concerned with how we may want to live in future worlds. Whereas science concerns conceptions that worked so far, design concerns what could work in the future, a future that is more interesting than what we know today. A design is always a proposal, a conjecture. Whether it delivers what it promises, whether it will work in the foreseeable future, cannot be known until it ceases to be a design and becomes part of its users' history.' [8.20] Certainly further research needs to be carried out within this field to attain the quality of media, design and product that would make it worthy of a place within our lives. Accordingly, the work in this thesis provides a sound platform from which further research projects can be developed. Although, as stated by Worbin, 'the amount of research papers and experimental prototypes is still greater than the amount of products to be found on the market' [8.21], this endeavour need not be disheartening.

8.2.7 Practical considerations

The following are additional practical factors that would need to be given consideration when using these dyes within a design.

Residual colour

The visible base colour and the slow fading time of some of the dyes leaves some residual colour on the substrate, however the strength of the developed colours, the imagery used and the frequency with which colour was re-introduced onto the substrate rendered it insignificant in the design work in this project. It was noted that, once they had been developed by the UV light and continued to be exposed to the fluorescent light, the 'Flame' and 'Palatinate Purple' dyes developed to a pale salmon and a pale green, respectively. 'Cardinal' dye develops to a dark pink and fades to yellow. Although the yellow colour was not initially seen when the dyes were developed by the LEDs, it eventually stains the substrate.

Substrate

Cotton drill (3/1 twill) was chosen as the substrate for this project based on the strength of the dyes' colour development. The appearance of the substrate could be considered further, as it essentially works as a screen on which an image appears. Yarns and weave structures affect the texture of a substrate and could be used to contribute to the suggestion of different moods, as they impact on the definition of a print and therefore any design or image created. Hopsack may give the background a more painterly

appearance and be appropriate for use with the dot mark, as it is reminiscent of the Impressionist painter's daub mark or the pointillist technique. The interaction of the substrate with the development of the dyes, by the light from the LEDs, would need to be considered. The distance from which the viewer observes the design would also affect the impact of the substrate.

Cover

Perspex covers were used to protect the user from the UV light of the LEDs during this experimental work. Although the Perspex blocks the development of the dyes by ambient and natural UV light, it does prevent the fabric substrate from being touched, distancing its tactile quality and thereby diminishing the purpose of its use. The application of UV absorbers to the substrate was considered so that a more tactile appearance could be created. However, as this would slow the dyes' development it was undesirable as it would increase the amount of time the LED light would be visible. If UV absorbers were to be used, their effect on the development of the dyes from the reverse side of the substrate would need to be explored.

Longevity of the dyes

The lifetime of a dye in a substrate is impossible to predict due to the complex chemical interactions that occur between the dye molecules and the matrix and these vary greatly from system to system [8.22]. Fatigue is a measurement of the lifetime of the molecule and the rate is dependent on the total amount of UV exposure and is adversely affected by the presence of acid and moisture, and these should be avoided if possible [8.23]. Additionally, constant UV exposure is more harmful to the dyes than the number of 'on/off' cycles [8.24]. However, a series of repeated 'on/off' cycles to develop the dyes by the LEDs, when they are printed on the cotton drill substrate, would be useful to give an indication of how long the dyes would last, and the subsequent impact this would have on a design. Although the use of UV absorbers will extend the life of photochromic dye, it will also reduce its colour intensity [8.25]. The incorporation of hindered amine light stabilisers, however, can enhance the photostability of the dyes [8.26].

The tests on these dyes were able to be carried out in a controlled environment however season and latitude would also indirectly affect their development, as indoor heaters and cooling systems would affect the ambient temperature of a room. To artificially make

the dyes fade more quickly, heat could be applied. This would need to be greater than 30°C and usually some colour intensity is lost [8.27].

8.3 Summary

Ordinarily placement, proportion and depth of shade of colour are all elements to be considered when creating a design. However, each of these factors takes on a new significance when applied to these dyes. Their ability to move influences the dynamic between each of the colours, either adjacent to, and/or as part of a larger design (depending upon the proportion of each colour used). Therefore, a new methodology, based on the dyes' placement and sequencing, was revealed as necessary when designing with these dyes. Additionally, the amount of time for which the dyes are developed and the intervals between their development influences the colour change that is observed and can be used to vary the pace of the movement of imagery or perceived sense of tension that is created.

The progressive exploration of design ideas led to the use of sequencing, both in a linear formation and in alternating placement on the substrate, to illustrate the concept of creating visual narratives using photochromic dyes. This design exploration has shown how the dyes have the potential to create a visual narrative. A change in colour in the *Clouds* design, using colours from opposite ends of the emotional and fading spectrums, has been able to be effected, although their ability to evoke a change in emotion in the viewer would need to be explored on a larger scale. The potential of the dyes to create a visual narrative, using alternating development of the 'Flame' and 'Palatinate' dyes, and abstract representational imagery, in the *Sea lapping shore* design, has been illustrated. However, the creation of a change in emotion, using the combined elements of design to create a change in tension has been limited. It has, though, been shown how these elements could be used and further exploration on a larger scale may be able to achieve this.

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Chapter 9

Overview of Findings and Suggestions for Future Work

Overview of Findings and Suggestions for Future Work

This chapter sets out the main findings of an investigation into achieving visual narration using photochromic dyes on a textile substrate, with the ability of the dyes' colours to capture emotions ranging from joy to sadness set as the parameter for this exploration. During this research numerous areas, predominantly to explore the dyes' application within a design context, were also highlighted as worthy of further investigation.

9.1 Overview of Findings

9.1.1 *Designing with photochromic dyes*

Initial experimental tests highlighted that working with dyes that are not able to be seen challenges habitual working practices until they became more second nature. Although surface design is a visual (as well as a tactile) medium, working with these dyes, whether for observations or design decisions, has reinforced the importance and place of our visual sense and perception.

Tacit knowledge enables working with conventional dyes and colours to be with a sense of freedom however familiarity needed to be gained with using photochromic dyes, that move and are eventually unable to be seen. Knowledge of the use of colour, and the way it is applied within static designs, provided a benchmark against which to highlight the differences in the way that these dyes can be used, illustrating that assumptions cannot be made about their application when they are used within a printed medium.

Although the dyes that were available for use covered the colour spectrum, their different fading speeds determined the way they would be applied. The blues and purples faded more quickly than the oranges and yellows whilst the fading speed of the grey dyes placed them in between these colours, and this order needed to be considered when planning their placement and sequencing. As a simple example, if wanting to create the image of an object with a shadow beside it, the placement of 'Midnight Grey', to illustrate the shadow, beside the blue of 'Palatinate Purple', representing the object, would result in the object fading before the shadow. If the image was printed with a slower fading dye, such as the orange of 'Flame', the shadow would fade before the object. However, orange may not be the desired choice of colour. Although a solution may be to use a colour other than grey for the shadow, this would raise the question of representing what is familiar to us in an unfamiliar way.

9.1.2 Design process

Initial design tests revealed that a new methodology, based on placement and sequencing, was needed. Although based on a more calculated approach, these elements still needed to be trialled, as they were applied together within a design, to see if the dyes' colours and movement created the desired visual effect. The initial design development work, with *Fading stripes*, *Tree, bug and planet* and *Clouds*, served to inform how to approach using the new methodology. This work highlighted that consideration needed to be given to the current intensity to be applied to any dye/s to increase or decrease its colour strength and the dye/s to which an increased (or decreased) development time would be applied to create an increased (or decreased) speed of development, as each decision would impact on the rest of the design. A subtle shift to focusing more on the movement aspect of the dyes led to the use of the simple imagery of the sea and the shore to illustrate the components of narrative with which we are familiar, enabling the interlinked movement, placement and colours of the dyes, as they worked together, to be demonstrated. The observations of the dyes' interactions in this sequence provide a basis from which to further explore these dyes.

The initial approach, based on answering design questions, was very methodical and, from a design perspective, seemed more technological in its structure. This approach changed the further into design development the work progressed and became more iterative, with the results providing information for reflection and comparison. It was noted that the designs that were being created were progressively simplified, to return to the familiar, from which exploration could then again move outwards. As more familiarity with the dyes was gained, more ways in which they could be explored within designs were revealed. Whilst the design aim drove the use of the technology, working with these dyes involved moving between both the technical and the design processes as the project unfolded.

Researching a visual medium that is not always visible also highlighted the importance of recording the work that was being carried out so that photographing and filming the dyes became an integral part of the research process. Storyboarding the photographs was invaluable for reflection whilst filming enabled the subtleties of this moving medium to be seen. However, both are very consuming of resources, particularly of time and computer hardware space.

The overall body of work in this thesis provides a good working model, through the development of storyboards, of the process of working with and assessing these dyes that are not able to be seen.

9.1.3 Colour and movement

The theoretical research on colour showed that it can be used in a diversity of combinations, proportion, placement, motif or abstraction and applications to convey an emotional experience to the observer.

The experimental tests revealed that the development of the dyes was consistently brighter on cotton drill therefore this was chosen as the substrate to use in this project. In sunlight, it was easier to observe the photochromic colours and their movement in less pictorial designs as there was less interplay between image and colour, whilst images that show more than one motif, or more than one part of a motif, moving appeared to have more visual impact than a single motif moving on its own.

Pigment, as a permanent colour, appeared to act as an anchor within designs, whilst a complete change in the colour visible and the appearance of a design occurred when the photochromic dye was hidden within a pigment substrate. However, the movement of photochromic dyes beside photochromic dyes appeared more organic than photochromic dyes beside pigments. As the dyes were developed or faded in their differing colours, in sunlight, the illusion of depth was created on a flat surface.

Although the dyes were initially developed for use in sunlight, testing showed that when developed by UV LEDs, when applied to the textile substrate, their colour intensity could still be very bright. When developed at a range of currents the intensity of their colour increased. It was also shown that developing the dyes with artificial UV light enabled their time of development to be controlled. After extensive testing of the dyes, it was concluded that their development with artificial UV light would enable their colour interactions to be sufficiently managed to enable the project aim to be explored.

9.1.4 Developing the dyes with artificial UV light

The approach to the work involved producing mechanisms that provided a test environment in which the capabilities of the dyes could be explored. The small manually controlled array provided the first opportunity to observe the dyes when

developed by a platform of artificial UV light, with the results providing an understanding of how their development and fading impacted upon the visual effects created. The functions of the larger computer programmable array helped considerably to progress the research by providing a more refined ability to control the dyes' development at varying intensities, at specified times and for defined periods of time.

9.1.5 *Design development to create a visual narrative*

Although the dyes move, their fading speeds define the areas of their placement as either 'fast' and 'slow' areas of colour and this impacts every aspect of a design. As placement and sequencing were highlighted as the basis for the methodology to be used, the use of the dyes was narrowed down to that of two colours within each of the *Clouds* and the *Sea lapping shore* sequences. This enabled the movement of the dyes to be more focussed upon.

Ultimately, linear sequencing enabled a change in colour in the *Clouds* design, using dyes from opposite ends of both the emotional and fading spectrums, to be created, although their ability to evoke a change in emotion in the viewer would need to be explored on a larger scale. The potential of the dyes to create a visual narrative, using alternating development of the 'Flame' and 'Palatinate' dyes, and abstract representational imagery, in the *Sea lapping shore* design, has been illustrated. However, the creation of a change in emotion, using the combined elements of design to create a visual narrative that showed a change in tension, has been limited. It has, however, been illustrated how these elements of design, such as proportion, placement and intensity of colour, are able to be combined with controlling the dyes' development times. Although something not immediately or materially apparent was not able to be brought out, evoked or led forth [9.1], this body of work has been able to show how the colours and movements of these dyes work together and further exploration on a larger scale may be able to more fully achieve this aim.

9.1.6 *Stylistic techniques of French Impressionist films*

The stylistic techniques in two French Impressionist films were observed and analysed to provide a range of ways for exploring the practical capabilities of photochromic dyes and they provided a very appropriate starting point for this exploration. At the scale at which the dyes were developed, their potential for use as transitional techniques, within

the creation of a narrative, was illustrated. Their configurations also provided a point of reference for ways of developing the dyes to create representational abstract imagery that could also be explored on a larger scale, illustrating how they can be used in this way to contribute to the creation of a visual narrative. Further exploration, on a larger scale, would determine their ability to assist with the expression of feelings.

9.1.7 Scale

This research has shown how scale affects the creation of colour and movement interactions using these dyes. Within the constraints of the size of the surface area being developed the extent of the dyes to create a visual narrative has been illustrated. The dot marks created by the LEDs have been useful for observing the dyes' colours as they have been developed and then move, and the relationship between each of the factors that contribute to the way in which the dyes appear on the substrate. Using a larger sized array would provide a larger surface area for use, enabling more colours to be visible on the substrate at any time, depending upon the design. However there would still be the inherent fundamental aspect of the dyes' fading, thereby decreasing the amount of colour that is seen on the substrate, unless the dyes were constantly being re-developed. Overall, the size of the large array has been useful for showing the movement of the dyes and how their fading speeds and colours appear and can interact together. It has also laid the groundwork on which further design development can be built, and demonstrated the potential the dyes have for being used as part of a larger design, where their colour and movement could interact more fully together.

9.2 Suggestions for Future Work

The research for this project has laid a solid groundwork from which numerous areas of further research can be undertaken. They are mainly ways of exploring the dyes' application within designs. They include their development by both natural and artificial UV light.

9.2.1 Development of the dyes with natural UV light

1. A comprehensive study of the fading patterns and the subsequent colours that the dyes appear in a range of natural UV light conditions would give an overview of their colour changes and assist with their application within designs. This could include the effects that can be created using mixed photochromic dyes (either mixed by printing or within the same system).

2. Explore designs that utilise and reinforce the dyes' changing colours in a space where natural UV light levels regularly fluctuate.
3. The subtle luminous effect created when photochromic dyes are placed beside another photochromic dye or beside pigment and developed in sunlight could be further explored.
4. Experiment with the shifting colour development of the dyes for use on fashion garments using varying natural UV light levels, the varying colour development created by using different weights of fabric and utilising different combinations of fibres within a fabric and therefore the subsequent garment.

9.2.2 Mark making and colour interactions

1. Explore the application of the dyes to the substrate with a paintbrush to create a range of brush marks, layered effects or washes.
2. The Impressionist painters, using their daub marks, were able to create the sensation of shimmering light or water with the static medium of paint. The movement of coloured daubs of photochromic dye, created by either a screen print or a paintbrush, when developed by sunlight or artificial UV light, may create similar effects.
3. When photochromic dyes develop, the residual dye is not always very noticeable. A design could be printed using a pale colour of non-photochromic dye and overprinted with photochromic dye. When the photochromic dye develops, the initial print, or part thereof, would disappear from view as the photochromic print took its place, or the resulting developed colour may become a darker shade. Mixing photochromic dyes with permanent dyes in varying quantities, either together in the print paste or by overprinting, could also be explored.
4. The creation of shadows within imagery, based on the movement of the dyes and the use of colours other than grey, could be used as a basis to inform the development of an effect similar to that created by the trompe l'oeil technique.

9.2.3 *UV LEDs and UV LED arrays*

1. The difference in the hue and shade of some of the dyes, when developed by 370nm and 400nm of UV light, showed how the wavelength developing the dye affects its resulting colour. Observing each of the dyes as they were developed by a range of UV LEDs, for example, from 360nm-410nm, would show the strength of colour development and hue of each dye at each wavelength.
2. An array that enabled the dyes to be developed by different wavelengths of UV light would enable the development of the different hues and variations of shade that these create and increase the colour palette for use within designs.
3. Explore the effect that different lens angles, different sizes of LEDs and more high powered LEDs have on the colour and performance of the dyes.
4. An array that enabled individual LEDs to develop the dyes at different strengths of current and at defined times would widen the scope of design development.
5. Developing the dyes on a larger-sized array would enable their movements to be explored on a larger scale. The Flash programme could be used to explore design development and to determine the size of array to build.
6. Developing the dyes with a light source that did not show the bright UV light through the substrate would enable their colours and movement to be explored in a different way.
7. Once familiarity had been gained with the way the colours of the dyes subtly shift, their colour development could be explored on a larger scale to enable the intuitive aspect of design development to be utilized more fully, with the intention of determining/understanding the full potential of the movement of colours of the dyes in creating emotive designs in an interior space, for example, on a large canvas.
8. Doing a series of repeated “on/off” development cycles of the dyes by LEDs to see how long the dyes last when developed in this way would give a projection of how long their application on a cotton drill substrate would last.

9.2.4 Development of the dyes with artificial UV light

1. Developing the dyes on a larger array would enable the dot mark that the LEDs create to be used to build up a picture in a way similar to the dots of the pointillist technique and the daub marks of the Impressionists.
2. Explore the creation of an undulating shifting surface of colour (referencing Rothko's paintings), by developing and re-developing the dyes, for different amounts of time and at appropriate intervals, over a larger surface area.
3. With considered placement, the dyes' colours may be able to create patterns in a way similar to those of the kaleidoscope. This would require an array that enabled different wavelengths of UV light to develop the dyes within the same position. In that way, the colours of mixed dyes may be more fully utilised. The configurations of the stylistic film techniques could be used as an initial starting point.
4. Explore the creation of psychedelic multi-coloured patterns that fully incorporate the lights of the LEDs.
5. Explore the development of the dyes in the following suggested sequences using individual or mixed dyes:
 - it may appear to be changing position, like a flower growing from seed, blooming then withering and dying.
 - the image could slowly morph into a completely different image by way of changing shape progressively as it was developed from left to right.
 - a completely different image could appear in each consecutive development.
6. Explore the combination of different development times (both how long a dye is developed and the intervals in between their development) with different depths of shade of the dyes' colours.
7. Develop the dyes in designs, using the same principle as the *Tree, bug and planet* design, to further explore the development of the dyes' colours and inseparable fading speeds, using varying light configurations.

9.2.5 Creating a code language

Creating a language to specify dynamic pattern creation could be used to drive an LED display. For example, input from man-made sounds, or from sounds of the landscape, could be picked up by sensors that would develop specific light patterns. These would then develop specific dyes and therefore specific colours and lead to the creation of spontaneous patterns. For example, the louder the sound, the brighter the dye developing a certain rhythmic pattern. The quieter the sound, the gentler or slower the light pattern and subsequently the colours developed. Sensors could also be used to pick up input from movement outside of a building or from natural UV light, for example, on a bright day or a dull day.

9.2.6 Different substrates

1. There was a noticeable difference in the colour development of the ‘Aqua Green’, ‘Cardinal’, ‘Flame’ and ‘Palatinate Purple’ dyes when they were printed on wool twill and this could be exploited. For example, wool twill pieces could be woven with cotton yarns in a cloth. If the weave structures were planned to fit in with the overall design of the fabric, and a design then printed on this woven substrate, the developed dyes on the printed wool would provide additional colours, as well as a different texture, giving another creative aspect to the design.
2. Experimentation of the devoré process may create interesting three dimensional effects when using photochromic dyes. Likewise, laser cutting, as an alternative to the chemical process, could be used to experiment with creating various depths of relief within the substrate. Experimentation with dye colour and strength, placement, development and fading coordination, and matching/mismatching the print with the burnt out area, using either the devoré or the laser cutting processes, may enhance the visual effects created by these dyes.
3. The effect created by printing the dyes on a felted substrate and developing them with LEDs, either embedded within or from outside of the substrate, could be explored.

9.2.7 Monofilament

1. The use of a backing substrate behind woven extruded polypropylene, containing photochromic dyes, may resolve the problem of the visibility of an artificial UV light source if it was used to develop the dyes. As the backing substrate would be in view

when the polypropylene was undeveloped, consideration would need to be given to its surface appearance. The thickness of the backing substrate and its effect on the development of the dyes would need to be explored.

2. Stitching the monofilament onto a substrate, with or without printed photochromic dyes, would provide an alternative use of the dyes in this medium. The extent to which they then developed would need to be ascertained.

9.2.8 Multifilament

The Ram extruder was used to extrude the photochromic dyes within this project, as it was faster and used less material than the larger, production Lab-Spin extruder, used to make multifilament yarn. The different sized nozzles of the Lab-Spin extruder enable different thicknesses of multifilament to be produced. The multifilament yarn could then be drawn and twisted in preparation for use in weaving and knitting.

9.2.9 Alteration to strength of dye colour

The ratio of dye to binder remained consistent throughout this project, however this could be researched further, for each individual dye, to minimise the base colour that appeared on the substrate for each colour. This may vary according to the substrate used.

9.3 References

[9.1] D. Bordwell *French Impressionist Cinema: Film Culture, Film Theory, and Film Style*. 110-111 (1980)

Appendices

Appendix A Photochromic dyes tested on six different substrates

1. 'Aqua Green', 'Flame', 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in Section 5.2.1.
2. 'Oxford Blue' print paste was made using the method as described in Section 5.2.2.

Substrates used:

Crinkle cotton, cotton voile, habotai silk (thick), habotai silk (light), silk chiffon, and cotton/linen mix. All substrates were supplied by Whaleys (Bradford) Ltd.

Printing:

Each dye was printed on a square (15cm x 15cm) piece of each substrate following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix B.1 Bird design

1. 'Flame', 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in Section 5.2.1.
2. 'Oxford Blue' print paste was made using the method as described in Section 5.2.2.

Substrate used:

Silk was chosen so the dyes could be observed when printed on a soft, lightweight fabric. It also has a shiny finish to its surface. As the background of the design was to be cream, the colour of the fabric was incorporated into the design.

Printing on silk:

All of the motifs were on the one screen. 'Rush Yellow' was used to print the grapes, 'Palatinate Purple' for the swirls, 'Oxford Blue' for the leaves, and 'Flame' for the bird.

1. A piece of lightweight silk fabric (27cm x 35cm) was placed on the print table.
2. Newsprint was used to cover the areas of the fabric where the motif was not to be printed.
3. Steps 3 & 4 of the method as described in Section 5.2.4 were followed.
4. The appropriate print paste corresponding with the motif to be printed was placed on the screen, using a spatula, in front of the magnetised rod.
5. Step 6 of the method as described in Section 5.2.4 was followed.

6. The magnetised rod was thoroughly washed and dried.
7. Steps 2 to 6 as above were repeated until each motif was printed. (Alternatively, separate screens could be used for each different colour of motif.)
8. The printed fabric sample was carefully lifted off the print table onto a piece of A3 paper.
9. The fabric sample was finished following the method as described in Section 5.2.5.
10. The print screen and magnetised rod were thoroughly washed with the power hose and left to dry.

Appendix B.2 Bird design

1. Each of the print pastes was made using the method as described in Section 5.2.1.

Substrate used:

Linen was chosen as the substrate because it is thicker, of a heavier weight and has a more textured surface than silk.


Printing on linen:

‘Aqua Green’ was used as the background colour. ‘Palatinate Purple’ was used for the bird and ‘Flame’ for the remainder of the images. All of the motifs were on the one screen and the background was on a second screen.

1. A piece of cream linen (27cm x 31cm) was placed on the print table.
2. Steps 2 to 7 under ‘Printing on silk’ as above were followed.
3. The screen to be used to print the background was placed on the print table.
4. Steps 4 to 7 of the method as described in Section 5.2.4 were followed.
5. The printed fabric sample was carefully lifted off the print table onto a piece of A3 paper.
6. The fabric sample was finished following the method as described in Section 5.2.5.
7. The print screen and magnetised rod were thoroughly washed with the power hose and left to dry.

Appendix C Stripe design

1. ‘Aqua Green’, ‘Flame’ and ‘Palatinate Purple’ print pastes were made using the method as described in Section 5.2.1.
2. ‘Oxford Blue’ print paste was made using the method as described in Section 5.2.2.

3. 'Brown'  print paste was made by mixing together equal quantities of 'Flame' and 'Palatinate Purple' (7g of each).

Substrate used:

Linen fabric was again chosen as the substrate to observe whether the difference in the design affected the appearance of the dyes on this fabric.

Printing:

The stripe design was separated onto two screens for printing. The dyes were printed following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix D.1 Photochromic dyes tested on 14 different substrates

1. 'Rush Yellow' was chosen as it was a dye that dissolved without heating. 'Oxford Blue' was chosen as it was a dye that required heat to dissolve and is a pale dye. They are also contrasting colours.
2. 'Rush Yellow' print paste was made using the method as described in Section 5.2.1. 'Oxford Blue' print paste was made using the method as described in Section 5.2.2.

Substrates used:

Acrylic, cotton drill, cotton poplin, linen, nylon voile, nylon 1, nylon 2, polyester 1, polyester 2, silk, silk/viscose velvet, tricot, wool twill and wool serge.

Printing:

Each dye was printed on a square (6cm x 6cm) sample of each substrate following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix D.2 Photochromic dyes tested on three different substrates

1. 'Aqua Green', 'Flame' and 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal' print paste was made using the method as described in Section 5.2.2.

Substrates used:

Cotton drill, cotton poplin and wool twill.

Appendix E Trees and circles

1. 'Aqua Green', 'Flame', 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal' and 'Oxford Blue' print pastes were made using the method as described in Section 5.2.2.
3. 'Green' pigment print paste was made using equal parts 'Imperon Yellow KR' and 'Imperon Blue KRR' pigment (1ml of each) in 100g of Bricoprint binder SF20E.

Substrate used:

Based on the results from Section 5.3.2 each design was printed on a piece of A4 sized cotton drill fabric.

Printing:

The following 9 prints were made using the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5:

1. A simple outline of a tree printed with 'Aqua Green' dye. Apples on the tree were printed with 'Cardinal' dye (Figs. 5.24 and 5.25).
2. A simple print outline of a tree printed with 'Green' pigment. The apples on the tree were printed with 'Cardinal' dye (Figs. 5.26 and 5.27).
3. A solid tree printed with 'Aqua Green' dye (Figs. 5.28 and 5.29).
4. A solid tree printed with 'Green' pigment. Apples on the tree were printed with 'Cardinal' dye (Figs. 5.30 and 5.31).
5. A solid tree printed with 'Green' pigment. Leaves were printed on top of the pigment with 'Aqua Green' dye (Figs. 5.32 and 5.33).
6. A collection of different sized solid circles printed with 'Imperon Red KGR' pigment. These were half-overprinted using the same screen with 'Cardinal' dye (Figs. 5.34 and 5.35).
7. A collection of different sized solid circles were printed with 'Imperon Red KGR' pigment. These were half-overprinted using the same screen with 'Rush Yellow' dye (Figs. 5.36 and 5.37).

8. Stripes of varying widths were printed with 'Flame' dye. These were half-overprinted with different sized solid circles using 'Cardinal' dye (Figs. 5.38 and 5.39).
9. Stripes of varying widths were printed with 'Imperon Orange KRL' print paste. These were half-overprinted with different sized solid circles using 'Cardinal' dye (Figs. 5.40 and 5.41).

When pigment and photochromic dyes were used on the same sample, the pigment was printed first and the sample dried in the Gallenkamp Hotbox oven. The sample was then printed with photochromic dyes.

Appendix F Abstract shapes

1. 'Aqua Green', 'Cardinal' and 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
2. 'Imperon Red KGR' and 'Imperon Yellow KR' pigment print pastes were made using the method as described in Section 5.4.3.

Substrates used:

Cotton drill

Prints:

The following 9 prints were made using the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5:

1. 'Aqua Green' dye was printed on the substrate. A stripe design using 'Cardinal' dye was printed on top of this (Figs. 5.42 and 5.43).
2. 'Cardinal' dye was printed on the substrate. 'Palatinate Purple' stripes were printed on top of the 'Cardinal' dye (Figs. 5.44 and 5.45).
3. 'Imperon Red KGR' pigment was printed on the substrate. A 'Palatinate Purple' scribble was printed on top of this (Figs. 5.46 and 5.47).
4. 'Imperon Red KGR' dye was printed on the substrate leaving the scribble design unprinted. 'Aqua Green' dye was then used to print the scribble design (Figs. 5.48 and 5.49).
5. 'Palatinate Purple' was printed on the substrate. 'Imperon Yellow KR' was then printed on top of this, leaving the scribble design unprinted (Figs. 5.50 and 5.51).
6. The 'Imperon Yellow KR' was printed on the substrate. 'Palatinate Purple' dye was then used to print the scribble on top of the yellow pigment (Figs. 5.52 and 5.53).

7. 'Imperon Yellow KR' was printed on the substrate. 'Palatinate Purple' was printed on top of this, leaving the scribble design unprinted (Figs. 5.54 and 5.55).
8. 'Aqua Green' was printed as the background colour. The scribble was printed in 'Palatinate Purple' on top of this (Figs. 5.56 and 5.57).
9. 'Aqua Green' was printed on the substrate leaving the scribble design unprinted. 'Cardinal' dye was used to print the scribble design (Figs. 5.58 and 5.59).

Appendix G Printing photochromic dyes on pigment

1. 'Aqua Green', 'Rush Yellow', 'Cardinal' and 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
2. 'Oxford Blue', 'Claret', 'Corn Yellow' and 'Flame' print pastes were made using the method as described in Section 5.2.2.

Substrate used:

Cotton drill

Printing:

The pigments and dyes were printed using two screens. Each pigment was printed on a square (20cm x 20cm) piece of each substrate. Each dye was printed in the shape of a smaller square (8cm x 8cm) on top of each pigment square. The pigments and dyes were printed following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix H Printing photochromic dyes side by side

1. 'Aqua Green', 'Corn Yellow', 'Flame', 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal', 'Oxford Blue' and 'Claret' print pastes were made using the method as described in Section 5.2.2.

Substrate used:

Cotton drill

Printing:

The dyes were printed using two screens. Photochromic dye was printed in a square (8cm x 8cm). Another colour of photochromic dye was printed in a larger square (20cm x 20cm) surrounding the smaller one. The dyes were printed following the method as

described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix I Fading strips

1. 'Aqua Green', 'Corn Yellow', 'Flame', 'Midnight Grey' and 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in section 5.2.1.
2. 'Cardinal', 'Claret', 'Oxford Blue', 'Sea Green' and 'Volcanic Grey' print pastes were made using the method as described in Section 5.2.2.
3. 'Plum Red' print paste was made using the method as described in Section 5.2.3.

Substrate used:

Cotton drill

Printing and observation method used:

The strips of printed fabric were initially placed in a row reflecting the colour groupings of the rainbow (Fig. 5.66). This placement was used as a starting point to see if dyes of similar colours had similar fading times. The dyes were photographed as they developed in sunlight for one minute, taken indoors away from direct sunlight and fluorescent light, photographed immediately (after approximately 10 seconds) and then every 15 seconds until there was minimal colour on the substrate. After noting the fading order of the dyes in this initial placement, see Table 10, the fabric strips were re-arranged, re-developed in sunlight (Fig. 5.67) and again photographed and observed. All timings used a clock timer and were approximate.

Appendix J Mixing photochromic dye colours by printing

1. 'Aqua Green', 'Corn Yellow', 'Flame', 'Midnight Grey', 'Palatinate Purple' and 'Rush Yellow' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal', 'Claret', 'Oxford Blue', 'Sea Green' and 'Volcanic Grey' print pastes were made using the method as described in Section 5.2.2.
3. 'Plum Red' print paste was made using the method as described in Section 5.2.3.

Substrate used:

Cotton drill

Printing and observation method used:

The dyes were printed on a square (5cm x 5cm) sample of fabric following the method as described in Section 5.2.4. After it had dried, the first layer of printing was developed in sunlight and each corner of the square outlined with a marker pen in preparation for the second layer of printing. This was a simple and effective way of outlining these simple prints and an efficient use of time. After the second layer of printing the dyes were finished following the method as described in Section 5.2.5.

The fabric samples were mounted on pages according to the fading order observed in Section 5.4.3, from slower fading dyes to faster fading dyes. For example, all samples printed with 'Flame', the slowest fading dye, and each one of the other dyes were mounted on one page, then all samples printed with 'Corn Yellow', the second slowest fading dye, and each one of the other dyes were mounted on another page, until all of the samples had been displayed. By arranging them in this way the visual impact of their speed of fading and colour changes could be closely observed.

Each page of samples was photographed as the dyes developed in sunlight for one minute, taken indoors away from direct sunlight and fluorescent light, photographed immediately (after approximately 10 seconds) and then every five seconds for two minutes, after which time the majority of their colour had faded. They were photographed at five second intervals to capture the changes that occurred. After two minutes they were photographed every 30 seconds until there was minimal colour on the substrate. All timings used a clock timer and were approximate.

A way of observing the numerous colour and fading combinations needed to be established. The paper print outs were laid out in sequence so that, by standing back and viewing them from a distance, overall trends in colour changes were easily seen and areas for closer analysis highlighted. Although the process of photographing, cropping, assembling images on computer pages and printing them out was time consuming, it was invaluable and necessary for observation.

The photographs serve as a record of the colours of the dyes at each stage. As they also enable repeated viewing of the fading patterns, as shown in Figure J.1, each individual pair within the individual colour groups was analysed one after the other using these

images. As the colours in the photographs on the computer screen were more true to life than those printed out on paper, these images were used for analysis. The photographs also enabled work to be carried out during inclement weather.



Fig. J.1 (a)
'Flame' dye mixed with other
dyes and developed in sunlight



(b)
The same samples 10 seconds
after removed from sunlight



(c)
The same samples 65 seconds
after removed from sunlight

The dyes were then observed first hand as they developed and faded on the textile substrate. Watching the actual movement of colours within the groups, with each one fading at different speeds and in different combinations, gave an indication of the visual effects that the dyes could create within an image. It also enabled the beauty of the colour changes and subtleties of their movement to be noticed and appreciated.

Appendix K Mixing photochromic dye colours in the same system

1. 'Aqua Green', 'Corn Yellow', 'Flame' and 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal', 'Claret' and 'Sea Green' print pastes were made using the method as described in Section 5.2.2.
3. 7g of each dye paste was mixed together in a beaker and stirred manually with a glass rod. This quantity was chosen as it mixes to make a sufficient amount of dye paste to cover the area to be printed.

Printing and observation method used:

The mixed dyes were printed on a square (5cm x 5cm) sample of fabric following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Each pair of prints was photographed as they developed in sunlight for one minute, taken indoors away from direct sunlight and fluorescent light, photographed

immediately (after approximately 10 seconds) and then every five seconds thereafter for two minutes after which the majority of their colour had faded. They were photographed at five second intervals to capture the changes that occurred. After two minutes, they were then photographed every 30 seconds until there was minimal colour on the substrate. All timings used a clock timer and were approximate.

Appendix L Dyes printed on sateen

1. 'Aqua Green', 'Corn Yellow', 'Flame', 'Midnight Grey', 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
2. 'Cardinal', 'Claret', 'Oxford Blue', 'Sea Green' and 'Volcanic Grey' print pastes were made using the method as described in Section 5.2.2.
3. 'Plum Red' print paste was made using the method as described in Section 5.2.3.

Substrate used:

Each dye was printed on a square (6cm x 6cm) sample of cotton drill and cotton sateen following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix M Devoré technique

1. 'Cardinal' print paste was made using the method as described in Section 5.2.1.

Substrate used:

Silk/viscose velvet

Printing:

The scribble design on an existing exposed screen was chosen on the basis of the thickness and convoluting layout of the line. It was printed on a sample (21cm x 26cm) of silk/viscose velvet using devoré paste.

1. The Gallenkamp Hotbox oven was preheated with the temperature set at 100°C. The Roaches Laboratory Oven temperature was set at 160°C dry heat. The oven timer was set at 10 minutes.
2. Devoré print paste was printed on the fabric following the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5, using the settings above.

3. The fabric was rinsed in cold water for 10 minutes.
4. It was then washed in warm water with agitation and superonic soap (to remove the silk fibres that had been burnt out).
5. The fabric was placed in the Gallenkamp Hotbox oven for 15 minutes to dry.
6. 'Cardinal' print paste was printed on the back of the fabric using the method as described in Section 5.2.4 and finished following the method as described in Section 5.2.5.

Appendix N Dye printed on pre-felt

1. 'Flame' print paste was made using the method as described in Section 5.2.2.

Substrate used:

Pre-felt is carded wool that has been lightly felted [N]. It does not have structural integrity, therefore further felting is necessary.

Printing:

1. The Gallenkamp Hotbox oven was preheated with the temperature set at 100°C. The Roaches Laboratory Oven temperature was set at 140°C dry heat. The oven timer was set at 5 minutes.
2. The 'Flame' dye was printed on a sample (20cm x 30cm) of pre-felt following the method as described in Section 5.2.4 using a plain print screen, and finished following the method as described in Section 5.2.5, using the settings above and dried in the Gallenkamp Hotbox oven for an additional 5 minutes.
3. The sample was then placed on a piece of cane mat, dampened with water and rolled up in the mat.
4. The mat was then placed on the floor and rolled backwards and forwards to create agitation and pressure on the pre-felt sample so as to complete the felting process.
5. The sample was then left to dry naturally.

Appendix O Extrusion of dyes using Ram extruder

Polymer used:

Polypropylene is a commonly used man-made polymer as it is easily extruded and inexpensive. It was supplied by Basell. The batch number was Moplen HP551M DE1421JO.

Polymer preparation

1. 30g of polypropylene was placed in a beaker.
2. 0.015g of photochromic dye was added to the beaker and stirred manually until the dye powder had thoroughly coated the polymer pellets. The quantity of 0.015g was the same ratio of photochromic dye powder to polypropylene polymer as that used for the printing mixture.



Fig. O Ram extruder

Extruding the polymer:

All equipment, including the dye head, was purpose-built by Extrusions Systems Ltd, Leeds.

1. The Ram extruder (Fig. O) was set at a temperature of 230°C and a pressure of 350 psi.
2. The water bath was filled with cold tap water and given time to settle to room temperature, i.e., 20°C.
3. The winder was set at the speed of 220 rpm.
4. The polymer/dye mix was placed in the barrel of the extruder, the barrel reheated, the piston lowered and the extruded polymer run through the water bath.
5. The resulting monofilament was wound onto yarn cones on the winder. It was not drawn.

Appendix P Fading of extruded dyes

Observation method used:

The monofilament cones were initially lined up according to the fading order of the printed dyes, Section 5.4.6. They were exposed to sunlight for one minute,

photographed, taken indoors immediately and photographed again (after approximately 15 seconds). From preliminary handling of the monofilament it was apparent that the extruded dyes take longer to fade than the printed dyes. Therefore, they were photographed every 30 seconds until the monofilament showed minimal colour. Their fading order was observed and noted.

The dyes were then re-arranged and lined up according to the order of fading noted, developed in sunlight, re-photographed as above and observed. As with the printed dyes, it was easier to observe the fading once the cones had been re-arranged.

Appendix Q Developing dyes with 365nm light tubes

Substrates used:

The cotton samples from Section 5.5.1 were used for this set of observations.

Developing the dyes and observation method used:

The printed fabric was placed on the shelf of a light box, 12cm below two 365nm UV light tubes. The tubes were turned on for a period of 60 seconds and timed by a stop clock. The dyes were observed as they developed. After 60 seconds the fabric samples were removed from the shelf to the table top immediately in front of the light box and their colours observed. Although practice and procedure ensured the time to transfer the fabric samples to the table top would be minimal, 1-2 seconds, their colour would have begun to fade during this time. Therefore, the dyes were continually observed. UV protective gloves and goggles were worn.

Appendix R Measurement of printed photochromic dyes developed by 400nm LED

1. 'Aqua Green', 'Corn Yellow', 'Flame', 'Midnight Grey' and 'Palatinate Purple' print pastes were made using the method as described in Section 5.2.1.
 2. 'Cardinal', 'Claret', 'Oxford Blue', 'Sea Green' and 'Volcanic Grey' print pastes were made using the method as described in Section 5.2.2.
 3. 'Plum Red' print paste was made using the method as described in Section 5.2.3.
- 'Rush Yellow' was not tested as it does not develop at 400nm [R.a].

Substrate used:

Cotton drill

Printing and method for development by light source:

Each of the Reversacol dyes was printed on a square (8cm x 8cm) of cotton drill fabric. Initial handling showed that as the fabric was held further away from the light source, colour development was not well defined. When the fabric was placed directly above the light source, the colour developed very quickly and in the shape of the light beam, i.e., a circle.

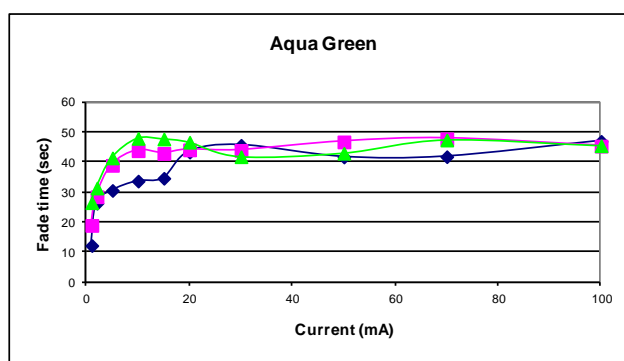
1. A 400nm LED was placed in a Mentor Prazisions-Bauteile LED tester (this will be referred to from now on as the 'tester').
2. The printed sample was placed over the tester's light source at a distance of 2-3mm.
3. The tester was manually switched on and timed for 2 seconds. A stop watch was used as the tester was unable to be programmed.
4. The tester was turned off and the sample was placed on a sheet of white paper.
5. A photograph was taken.
6. Measurements were taken when it appeared, to my naked eye, that the dye was no longer visible on the sample.
7. Steps 2–6 were repeated for intervals of 5 and 10 seconds for each sample.

Although the LEDs are not to be routinely safely used at greater than 20mA, they were tested at currents up to 100mA. This was deemed an acceptable risk to take to observe how brightly the dyes developed with a greater power source.

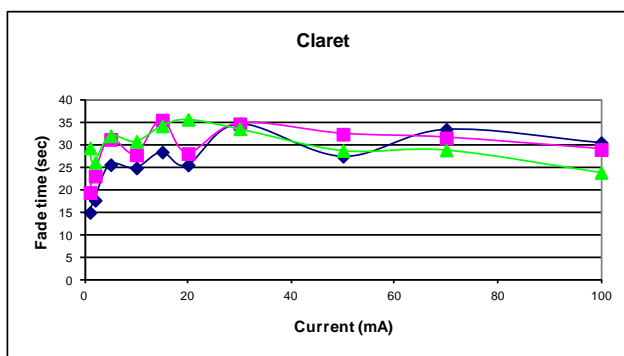
The temperature of the laboratory where this series of tests was carried out was 17°-18.5°C. Although a very general claim, typically for a 10°C increase in temperature, the dyes will lose half their colour strength and the speed of fade back will be halved [R.b].

Appendix R.1 Printed dyes developed by 400nm LED for 2, 5 and 10 seconds

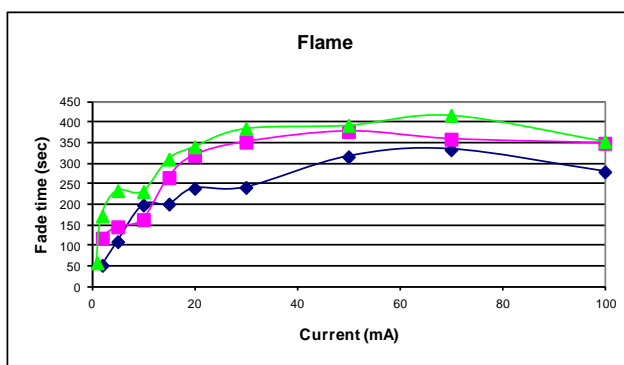
Aqua Green			
I(mA)	2sec	5sec	10sec
1	12.08	18.8	26.38
2	26.2	28.36	31.26
5	30.45	38.82	41.29
10	33.57	43.7	47.81
15	34.51	42.79	47.61
20	43.23	43.98	46.54
30	45.51	43.79	41.7
50	41.6	46.63	42.85
70	41.7	47.67	47.26
100	46.82	45.23	45.36



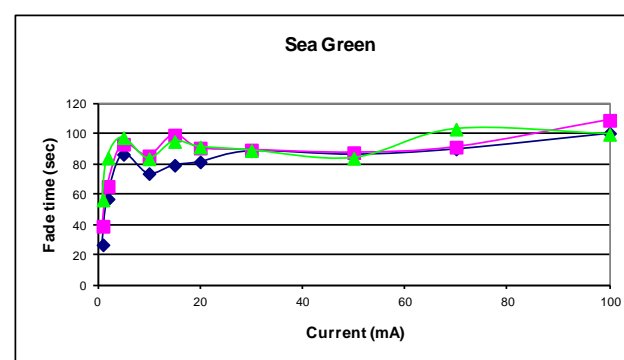
Claret			
I(mA)	2sec	5sec	10sec
1	14.86	19.3	29.22
2	17.57	22.95	26.01
5	25.48	31.11	31.92
10	24.76	27.67	30.69
15	28.29	35.39	34.11
20	25.42	27.95	35.57
30	34.57	34.57	33.48
50	27.35	32.26	28.64
70	33.35	31.42	28.76
100	30.38	28.85	23.76



Flame			
I(mA)	2sec	5sec	10sec
1			57.51
2	51.41	117.57	172.07
5	109.04	145.23	233.48
10	198.13	162.7	231.08
15	200.6	265.1	310.08
20	238.81	318.64	340.08
30	241.1	351.42	384.61
50	315.66	377.36	392.44
70	332.89	358.57	416.79
100	279.01	348.57	353.08

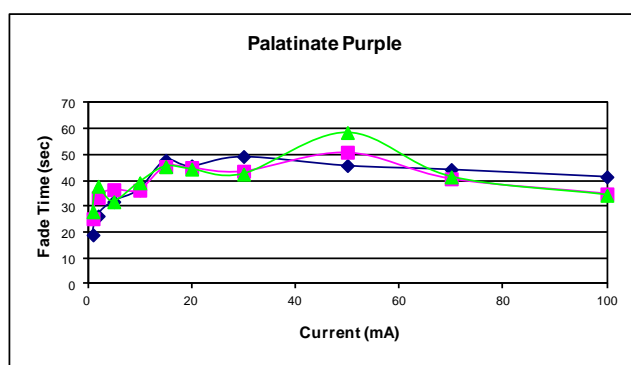


Sea Green			
I(mA)	2sec	5sec	10sec
1	26.52	38.77	56.11
2	56.79	65.08	83.86
5	86.2	92.92	97.23
10	73.55	85.23	83.29
15	79.05	98.98	94.7
20	81.23	90.38	91.1
30	88.51	89.1	88.73
50	86.23	87.35	83.66
70	89.76	90.98	102.85
100	100.16	108.7	99.42

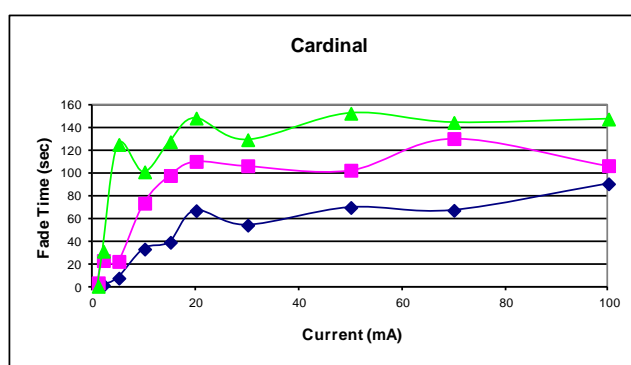


Printed dyes developed by 400nm LED for 2, 5 and 10 seconds

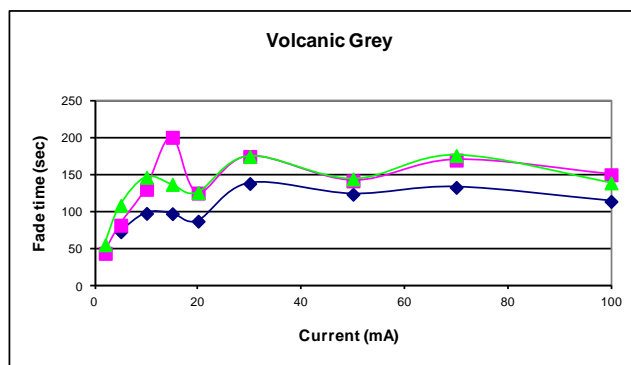
Palatinate Purple				
I(mA)	2sec	5sec	10sec	
1	19.06	25.32	28.01	
2	26.39	33.51	37.89	
5	31.92	36.57	31.88	
10	36.51	36.35	39.23	
15	47.92	45.51	45.45	
20	45.76	45.13	44.51	
30	49.39	43.7	42.57	
50	45.89	51.05	58.66	
70	44.36	40.76	41.48	
100	41.51	34.92	34.38	



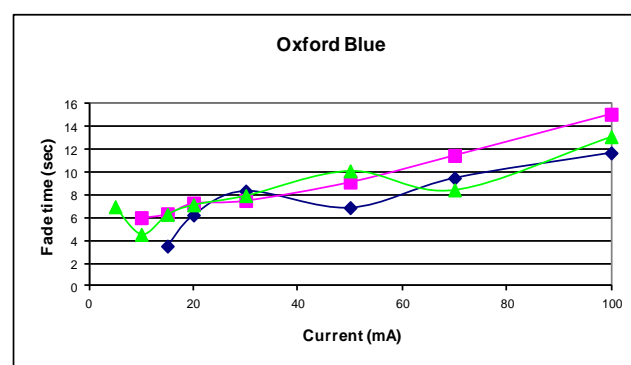
Cardinal				
I(mA)	2sec	5sec	10sec	
1	2.2	3.05	0	
2	1	22.67	30.85	
5	7.17	21.89	124.67	
10	32.7	73.06	100.58	
15	38.67	97.38	127.01	
20	66.45	109.76	147.83	
30	53.73	105.92	128.83	
50	69.26	102.01	152.07	
70	66.76	129.83	144.01	
100	90.07	106.04	147	



Volcanic Grey				
I(mA)	2sec	5sec	10sec	
1				
2		42.92	54.52	
5	72.08	80.94	107.69	
10	96.95	129.5	145.74	
15	96.54	199.82	136.2	
20	86.4	124.41	125.17	
30	137.34	173.89	173.91	
50	122.82	140.93	143.45	
70	132.14	169.04	175.26	
100	113.16	149.17	138.2	

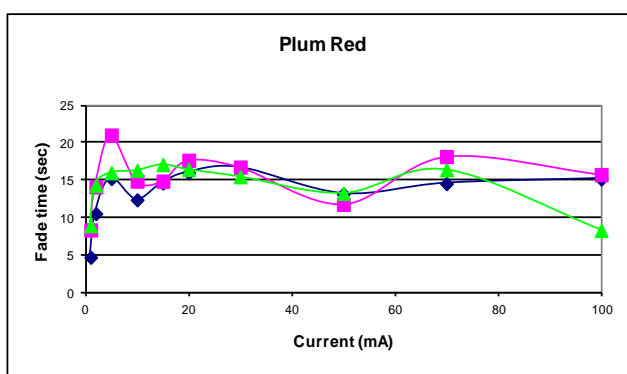


Oxford Blue				
I(mA)	2sec	5sec	10sec	
1				
2				
5			7	
10		6.04	4.57	
15	3.54	6.38	6.33	
20	6.27	7.32	7.17	
30	8.38	7.55	7.98	
50	6.92	9.17	10.15	
70	9.52	11.51	8.48	
100	11.73	15.13	13.16	

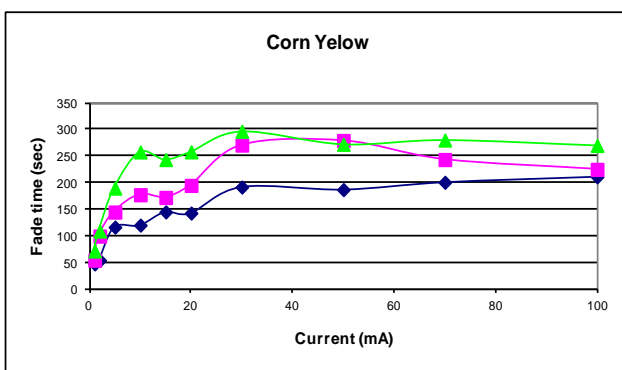


Printed dyes developed by 400nm LED for 2, 5 and 10 seconds

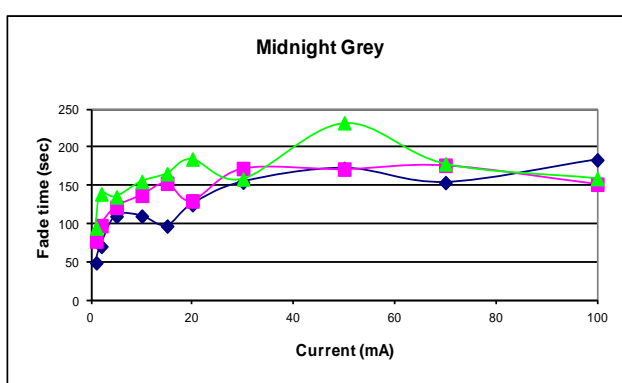
Plum Red			
I(mA)	2sec	5sec	10sec
1	4.67	8.33	8.89
2	10.51	14.11	14.3
5	15.2	21.01	15.98
10	12.36	14.86	16.29
15	14.61	14.85	17.08
20	15.98	17.64	16.42
30	16.61	16.73	15.45
50	13.14	11.76	13.23
70	14.52	18.14	16.38
100	15.14	15.73	8.26



Corn Yellow			
I(mA)	2sec	5sec	10sec
1	46.88	53.95	71.23
2	53.64	99.2	108.73
5	116.14	144.45	189.6
10	119.85	177.11	257.66
15	144.73	171.91	243.36
20	142.58	194.66	257.82
30	191.57	270.61	296.55
50	186.7	279.13	272.08
70	200.48	243.36	280.14
100	210.82	224.82	269.92



Midnight Grey			
I(mA)	2sec	5sec	10sec
1	48.7	77.33	94.36
2	70.23	97.45	138.89
5	109.7	121.42	135.1
10	109.92	137.17	155.17
15	96.88	152.98	165.48
20	124.82	129.8	184.71
30	154.32	172.23	158.52
50	172.36	171.53	232.19
70	153.81	176.53	178.37
100	183.53	151.68	159.12



Appendix R.2 Repeat experiments made by 400nm LED at 20mA for 5 seconds

I(mA)	'Oxford Blue'	'Plum Red'	'Aqua Green'	'Claret'
20	21.12	40.94	61.62	68.97
20	23.62	49.41	64.78	69.87
20	24	43.81	67.69	68.35
average	22.91	44.72	64.70	69.06
I(mA)	'Palatinate Purple'	'Sea Green'	'Corn Yellow'	'Cardinal'
20	106.97	170.41	253.28	281.25
20	85.62	171.59	254.75	260.75
20	90.57	168.72	264.87	285.41
average	94.39	170.24	257.63	275.80
I(mA)	'Midnight Grey'	'Volcanic Grey'	'Flame'	
20	297.16	410.12	573.94	
20	330.09	447.56	628.91	
20	296.63	364.65	506.65	
average	307.96	407.44	569.83	

Appendix R.3 Printed dyes developed by 370nm LED at 20mA for 2, 5 and 10 seconds

I(mA)	'Oxford Blue'	'Plum Red'	'Aqua Green'	'Claret'
2	20.68	30.31	28.94	49.14
5	26.25	37.53	54.52	56.69
10	25.03	42.9	43.1	58.25
I(mA)	'Rush Yellow'	'Palatinate Purple'	'Sea Green'	'Midnight Grey'
2	35.65	61.62	81.84	243.12
5	58.66	87.07	119	340.84
10	80.44	84.25	124.98	286.44
I(mA)	'Corn Yellow'	'Volcanic Grey'	'Cardinal'	'Flame'
2	191.34	245.63	309.81	435.01
5	237.2	349.87	342.97	535.26
10	324.72	454.78	450.9	659.96

Appendix R.4 Repeat experiments made by 370nm LED at 20mA for 5 seconds

I(mA)	'Oxford Blue'	'Plum Red'	'Aqua Green'	'Claret'
20	18.31	19.22	23.03	29.85
20	19.97	21.1	24.06	33.06
20	18.85	21.57	22.19	29.4
average	19.04	20.63	23.09	30.77
I(mA)	'Rush Yellow'	'Palatinate Purple'	'Sea Green'	'Midnight Grey'
20	38.09	64.59	95.07	176.79
20	36	64.34	93.47	154.03
20	33.63	62.63	99.13	149.4
average	35.91	63.85	95.89	160.07
I(mA)	'Corn Yellow'	'Volcanic Grey'	'Cardinal'	'Flame'
20	186.71	298.37	327.85	381.62
20	184.18	268.91	295.47	399.94
20	181	254.53	287.81	392.03
average	183.96	273.94	303.71	391.20

Appendix R.5 Measuring extruded photochromic dyes developed by 400nm LED

Substrate used:



Fig. R Extruded polypropylene sample

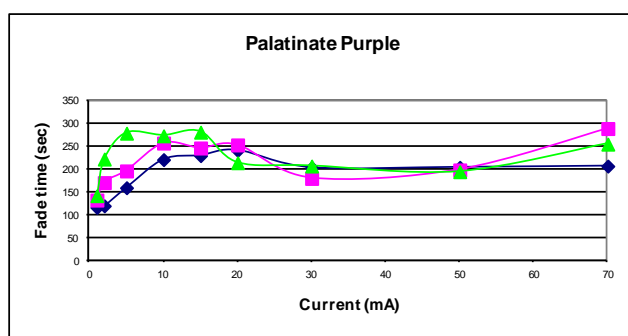
A 2cm square was cut out from the centre of a piece of card. Extruded polypropylene was placed side by side in rows to cover the area. Another layer of extruded polypropylene was placed on top of, and perpendicular to, the first layer (Fig. R). This was to imitate woven polypropylene. A sample was made for each colour of the extruded dyes.

Observation method used:

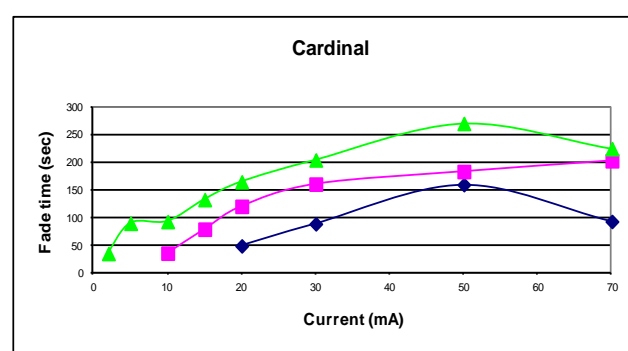
1. A 400nm LED was placed in a Mentor Prazisions-Bauteile LED tester.
2. The polypropylene sample was placed over the light source at a distance of 3mm.
3. Steps 3-7 in Section 5.7.2.2 were followed for each polypropylene sample.

Appendix R.6 Extruded dyes developed by 400nm LED for 2, 5 and 10 seconds

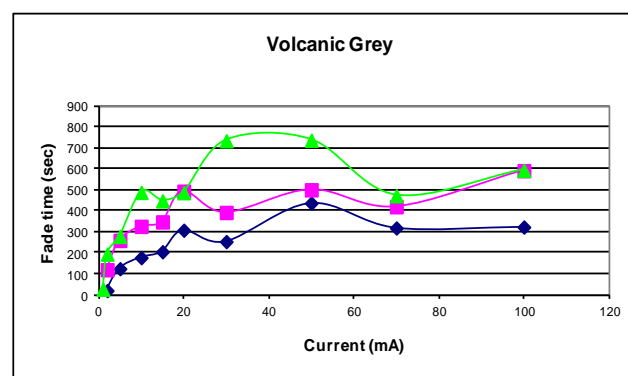
Palatinate Purple			
I(mA)	2sec	5sec	10sec
1	114.72	130.79	140.47
2	118.16	168.94	220.44
5	157.75	194.47	276.97
10	219.16	255.41	271.25
15	227.91	244.6	279.16
20	239.37	251.3	212.4
30	201.66	178.12	205.22
50	202.38	196.59	192.81
70	205.04	287.19	253.03



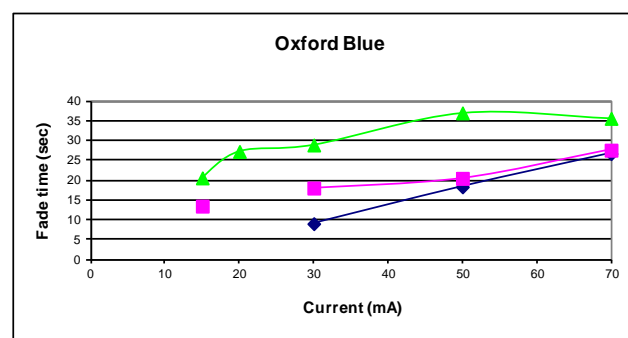
Cardinal			
I(mA)	2sec	5sec	10sec
1			
2			33.97
5			88.63
10		34.57	91.78
15		77.97	131.56
20	47.71	119.34	163.72
30	87.63	159.57	203.34
50	158.6	182.34	269.41
70	91.94	201.87	223.84



Volcanic Grey			
I(mA)	2sec	5sec	10sec
1			26.56
2	19.87	119.31	193.56
5	124.06	258.9	278.12
10	176.78	325.79	487.53
15	204.84	346.93	447.56
20	307.28	493.1	486.31
30	253.22	391.94	733.68
50	436.47	499.85	736.19
70	318	419.47	471.81
100	322.53	590.87	592.86

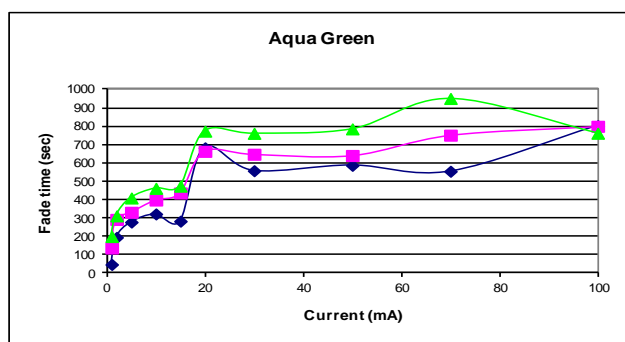


Oxford Blue			
I(mA)	2sec	5sec	10sec
1			
2			
5			
10			
15		13.47	20.59
20			27.26
30	9.03	18.03	28.9
50	18.33	20.47	37
70	26.72	27.59	35.62

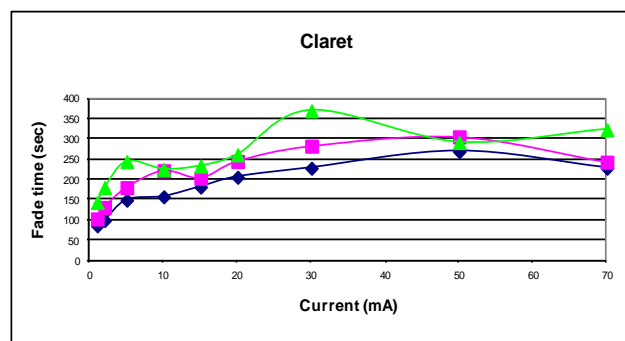


Extruded dyes developed by 400nm LED for 2, 5 and 10 seconds

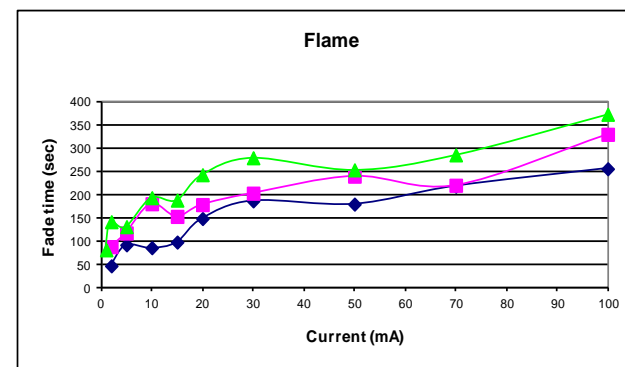
Aqua Green			
I(mA)	2sec	5sec	10sec
1	48.47	138	200.44
2	195.97	293.6	312.81
5	279.13	332.31	410.06
10	323.28	399.16	462.63
15	284.1	437.53	474.35
20	683.13	663.94	773.69
30	558.5	648.15	761.75
50	587.78	641.31	786.16
70	555.47	751.97	951.62
100	803.19	800.1	762.47



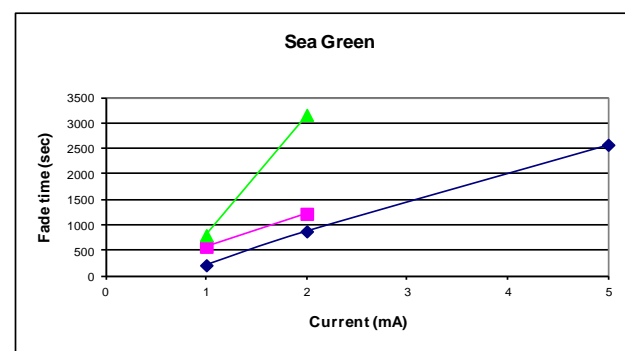
Claret			
I(mA)	2sec	5sec	10sec
1	85.03	102.1	142.62
2	98.21	130.43	179.62
5	148.31	179.28	243.72
10	156.69	221	224.66
15	180.75	202.69	232.78
20	204.97	244.09	260.5
30	227.28	281.84	369.16
50	268.28	304.75	290.92
70	227.31	242.19	322.31



Flame			
I(mA)	2sec	5sec	10sec
1			80.29
2	45.81	87.03	140.8
5	91	116.5	130.16
10	84.82	179.47	192.47
15	96.91	152.19	187.25
20	147.59	177.6	241.9
30	185.54	202.13	278.4
50	178.6	238.79	252.41
70	217.03	219.19	284.63
100	254.69	328.79	371.93

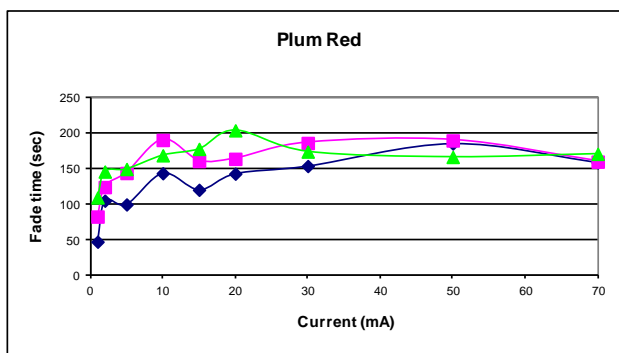


Sea Green			
I(mA)	2sec	5sec	10sec
1	209.82	573.17	801.04
2	875	1219.63	3162.6
5	2574.38		

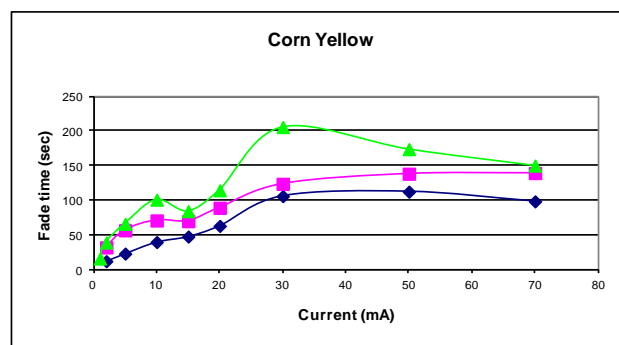


Extruded dyes developed by 400nm LED for 2, 5 and 10 seconds

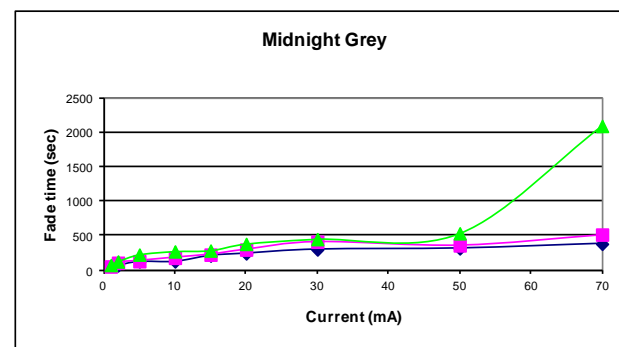
Plum Red			
I(mA)	2sec	5sec	10sec
1	46.22	81.59	108.5
2	103.9	123.07	144.91
5	98.64	142.89	148.51
10	142.52	189.33	167.75
15	119.22	159.69	176.79
20	141.88	162.79	202.88
30	152.65	185.11	172.98
50	184.36	188.64	165.45
70	157.7	158.83	169.78



Corn Yellow			
I(mA)	2sec	5sec	10sec
1			15.59
2	11.69	31.62	38.72
5	22.65	56.34	65.66
10	39.31	70.56	100.57
15	47.25	69.53	84.03
20	62.65	88.81	114.15
30	105.63	123.44	205.52
50	112.1	138.06	173.6
70	98.1	139.06	149.81



Midnight Grey			
I(mA)	2sec	5sec	10sec
1		50.44	71.78
2	65.75	103.93	123.31
5	122.38	127.29	223.42
10	123.38	176.35	269.41
15	208.03	222.28	281.97
20	239.78	295.91	378.06
30	296.68	410.25	447.93
50	312.78	356.78	532.31
70	378.67	513.45	2089.82



Appendix R.7 Repeat experiments made by 400nm LED at 20mA for 5 seconds

I(mA)	'Oxford Blue'	'Corn Yellow'	'Cardinal'	'Plum Red'
20	28.25	133.03	130.53	180.1
20	29.25	110.68	139.78	174.78
20	33.53	106.53	120.63	167.84
average	30.34	116.75	130.31	174.24
I(mA)	'Midnight Grey'	'Claret'	'Flame'	'Volcanic Grey'
20	233.53	287.12	326.43	414.94
20	278.41	252.09	318.35	421.87
20	240.44	230.1	336.75	337.47
average	250.79	256.44	327.18	391.43
I(mA)	'Palatinate Purple'	'Aqua Green'		
20	399.03	619.5		
20	399.44	617.9		
20	413.69	667.13		
average	404.05	634.84		

Appendix R.8 Extruded dyes developed by 370nm LED at 20mA for 2, 5 and 10 seconds

I(mA)	'Rush Yellow'	'Oxford Blue'	'Corn Yellow'	'Midnight Grey'
2	14.75	40.56	96.16	101.25
5	22.9	50.03	126.62	129.36
10	33.5	51.5	205.69	230.65
I(mA)	'Plum Red'	'Palatinate Purple'	'Claret'	'Flame'
2	155.97	184.44	231.1	134.67
5	228.72	231.96	318.44	169.81
10	239.62	281.52	360.63	204.81
I(mA)	'Cardinal'	'Volcanic Grey'	'Aqua Green'	
2	240.59	147.34	338.16	
5	271.53	341.66	482.03	
10	287.12	470.5	563.38	

Appendix R.9 Repeat experiments made by 370nm LED at 20mA for 5 seconds

I(mA)	'Rush Yellow'	'Oxford Blue'	'Corn Yellow'	'Midnight Grey'
20	33.06	60.47	125.97	149.4
20	25.42	58.72	112.22	118.02
20	26.47	61.03	146.16	144.25
average	28.32	60.07	128.12	137.22
I(mA)	'Plum Red'	'Palatinate Purple'	'Claret'	'Flame'
20	159.31	220.94	234.75	218.53
20	163.44	219.74	229.63	237.28
20	178.97	225.32	203.84	240.5
average	167.24	222	222.74	232.10
I(mA)	'Cardinal'	'Volcanic Grey'	'Aqua Green'	
20	290.65	365.7	424.56	
20	299.69	355.49	386.04	
20	234.38	395.6	419.07	
average	274.91	372.26	409.89	

Appendix S Developing dyes with fluorescent light

Substrate used:

The cotton drill samples from Section 5.5.1 were used for this observation.

Observation method of printed samples:

The printed samples were placed on a bench in the conditioned testing laboratory, where there was no natural UV light, exposed to the fluorescent lighting in the room and intermittently observed over a 20 minute period. The temperature in the laboratory was 18°C.

Substrate used:

The polypropylene samples from Section 5.7.2.6 were used for this observation.

Observation method of extruded samples:

The samples were placed on a bench in the conditioned testing laboratory, exposed to the fluorescent lighting in the room, and intermittently observed over a 60 minute period. The temperature in the laboratory was 18°C.

Appendix T References

[N] No author [WWW] <http://dreamspinfibres.ca/prefelt.htm> Accessed 13/01/12 (no date)

[R.a] No author *James Robinson Reversacol Photochromic dyes literature*. Accessed 22/05/08 (no date)

[R.b] Conversation with Claire Goddard, James Robinson - Vivimed Labs Europe Ltd (22/01/09)

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Email:carol.banks@mac.com (9/01/13)

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